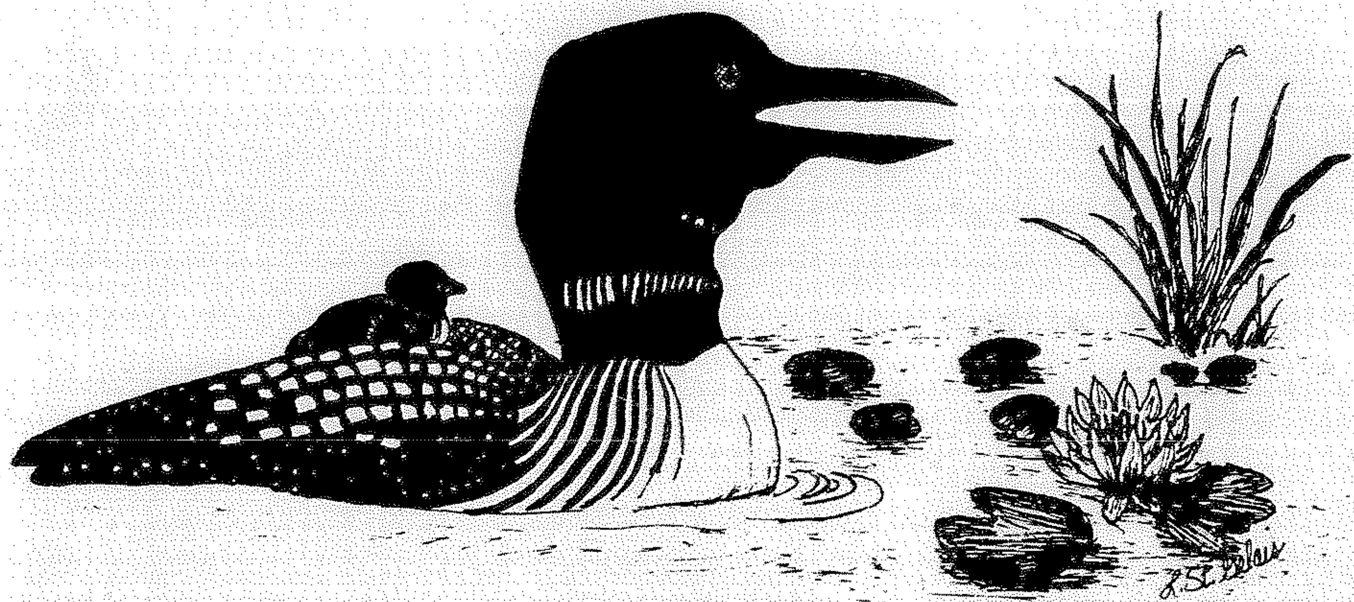
LONG ISLAND
1995
NH LAKES LAY MONITORING PROGRAM



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UNIVERSITY OF NEW HAMPSHIRE
COOPERATIVE EXTENSION

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PARAMETERS SAMPLED
NH LAKES LAY MONITORING PROGRAM

LAY MONITORS

BASIC PROGRAM
- Secchi Disk Depth
- Temperature Profile
- Chlorophyll a
- Dissolved Color
- Total Alkalinity
- Total Phosphorus

ADVANCED OPTIONS
- pH
- Metalimnetic Chlorophyll a
- Specific Conductivity
- Hypolimnetic Total Phosphorus
- Dissolved Oxygen
- Bacteria
- Fish Condition
- Rainfall & pH
- Aquatic Vegetation Surveys
- Motorboat Effects
- Watershed NPS Surveys
- Road Salt Runoff

STREAM MONITORING
- Observational Surveys
- Temperature
- Specific Conductivity
- Total Alkalinity
- Total Phosphorus
- Stream Flow
- Macro-Invertebrates
- Storm Event Sampling
- Bacteria

Freshwater Biology Group (FBG) corroboration with the lay monitor data includes assessment of 1) physical parameters (water transparency, temperature profiles, light transmission profiles and water color); 2) chemical parameters (dissolved oxygen profiles, "free" carbon dioxide, total alkalinity, pH, total phosphorus and specific conductivity profiles); 3) biological parameters (chlorophyll a, phytoplankton community and zooplankton community). Note: in addition to the above parameters, other measurements are often collected at the discretion of the FBG or at the request of the lake association.

PREFACE

This report contains the findings of a water quality survey of Lake Winnipesaukee - Long Island conducted in the summer of 1995 by the **Freshwater Biology Group (FBG)** of the University of New Hampshire and the Long Island Landowner's Association.

The report is written with the concerned lake resident in mind and contains a brief, non-technical summary of 1995 results as well as more detailed "Introduction" and "Discussion" sections. Graphic display of data is included, in addition to listings of data in appendices, to aid visual perspective.

ACKNOWLEDGMENTS

1995 was the thirteenth year the Long Island Landowner's Association participated in the **New Hampshire Lakes Lay Monitoring Program (LLMP)**. The Lay Monitors involved in the water quality monitoring effort were Phil and Barbara Parsons (Site 45), Robert Ainscow, Jack Dryer, John Dryer and Jerry Donovan (Site 49) and Edwin and Dorothy Hoffmann (Sites 61 and 64). Ed Hoffmann again coordinated the volunteer monitoring effort on Long Island and acted as liaison to the **Freshwater Biology Group (FBG). The Freshwater Biology Group** congratulates the volunteer monitors on the quality of their work, and the time and effort put forth. Funding for this volunteer monitoring effort was provided by the Long Island Landowner's Association.

The **Freshwater Biology Group** is a not-for-profit research program co-supervised by Dr. Alan Baker and Dr. James Haney and coordinated by Jeffrey Schloss. Members of the **FBG** summer field team included, Robert Craycraft (laboratory and field team coordinator), Benjamin Delisle, Sean Proll and Chris Rovaldi. Other **FBG** staff assisting in the fall included Jessica Chappel, Jessica Dunn, Laura Boddington and Allison Hamel.

The **FBG** acknowledges the University of New Hampshire Cooperative Extension for funding and furnishing office, laboratory and storage space. The College of Life Sciences and Agriculture provided accounting support and the UNH Office of Computer Services provided computer time and data storage allocations.

Participating groups in the **LLMP** include: The Center Harbor Bay Conservation Commission, Dublin Garden Club, Governor's Island Club Inc., Meredith Bay Rotary Club, The New Hampshire Audubon Society, Society for Protection of Lakes and Streams, Walker's Pond Conservation Society, United Associations of Alton, the associations of Baboosic Lake, Berry Bay, Bow Lake Camp Owners, Chalk Pond, Lake Chocorua, Cunningham Pond, Crystal Lake, Dublin Lake, Goose Pond, Great East Lake, Lake Kanasatka Watershed, Langdon Cove, Long Island Landowners, Lovell Lake, March's Pond, Mendum's Pond, Merrymeeting Lake, Milton Ponds Lake Lay Monitoring, Mirror Lake (Tuftonboro), Moultonborough Bay, Lake Winnipesaukee, Naticook Lake, Newfound Lake, Nippo Lake, Pemaquid Watershed, Silver Lake (Madison), Silver Lake (Tilton), Squam Lakes, Sunset Lake, Wentworth Lake and the towns of Alton, Amherst, Enfield, Errol, Madison, Meredith, Merrimack, Milan, Strafford and Wolfeboro.

LONG ISLAND
1995 NON-TECHNICAL SUMMARY

Weekly water quality data were collected at the Long Island deep sampling stations (45 Ese Li, 49 Green's Boathouse, 61 West Point and 64 Jonathan's Landing) between May 22 and September 25, 1995 while a July 25, 1995 sampling trip by the **Freshwater Biology Group (FBG)** was undertaken to augment the volunteer monitor data. The following section summarizes the 1995 Long Island water quality data and when applicable, incorporates historical data into the interpretation.

1) The 1995 Long Island water clarity (Secchi Disk transparency) measurements were high and averaged 8.6 meters (28.4 feet) at Site 45, 7.4 meters (24.4 feet) at Site 49 and 8.7 meters (28.7 feet) at Sites 61 and 64. Transparency values greater than 4 meters are typical of a clear, unproductive, lake while transparency values less than 2.5 meters are generally an indication of a highly productive lake. Secchi Disk readings between 2.5 and 4.0 meters are considered indicative of a moderately productive lake.

The 1995 seasonal average Long Island water transparencies were near the 1994 seasonal average water transparencies along the western side of the island (Sites 61 and 64) while the 1995 seasonal average Long Island water transparencies exceeded the 1994 seasonal average water transparencies along the eastern side of the Island (Sites 45 and 49). Refer to Figure 25, 27, 29 and 31 for a graphic depiction of the water clarity data.

2) The 1995 Long Island microscopic plant "algal" concentrations (measured as chlorophyll *a*) were low to moderate when collected by the volunteer monitors (range: 0.8 to 3.9 milligrams per cubic meter; mg m^{-3}) and well within the range of historical values. The seasonal chlorophyll *a* concentration averaged 1.5 milligrams per cubic meter at Site 45, 1.7 mg m^{-3} at Site 49, 1.2 mg m^{-3} at Site 61 and 1.4 mg m^{-3} at Site 64. Chlorophyll *a* concentrations below 3 mg m^{-3} are common to an unproductive lake while chlorophyll *a* concentrations above 7 mg m^{-3} are common to a productive lake. Chlorophyll *a* concentrations between 3 mg m^{-3} and 7 mg m^{-3} are considered characteristic of a moderately productive lake.

The 1995 seasonal average Long Island chlorophyll *a* concentrations decreased at each of the deep sampling stations, relative to the 1994 seasonal average chlorophyll *a* concentrations, and reflect the dry conditions characteristic of 1995 which limited the flushing of nutrients (conducive to microscopic plant "algal" growth) into the lake (Figures 26, 28, 30, 32). While low, the seasonal average chlorophyll *a* concentrations along the eastern side (Sites 45 and 49) of Long Island were higher than the seasonal average chlorophyll *a* concentrations documented along the western side (Sites 61 and 64) of the island.

3) The 1995 Long Island seasonal average dissolved lakewater color concentration, 8.6 platinate color units (ptu), was low and considerably less than the seasonal average of 21.9 ptu for **LLMP** lakes. Dissolved, color, or

true color as it is sometimes called, is indicative of dissolved organic carbon levels in the water (a by-product of microbial decomposition). Small increases in water color from the natural breakdown of plant materials in and around a lake are not considered to be detrimental to water quality. However, increased color can lower water transparency, and hence, change the public perception of water quality. Large amounts of dissolved color might occur naturally but can also occur during deforestation and development within the watershed. High color levels can actually mask the ability of the Secchi Disk transparency to predict chlorophyll levels. Dissolved color data collected by the **NH LLMP** volunteer monitors over the past ten years indicate dissolved color concentrations are typically higher during wet years (years with above average precipitation), when precipitation events flush highly colored water from the watershed into the lake.

4) The 1995 total phosphorus (generally considered the limiting nutrient for plant growth in freshwater systems) concentrations, measured in the surface waters, were low to moderate through most of the year with the single exception of a high total phosphorus concentration (103.2 parts per billion) documented at the 61 West Point sampling station on September 11. High phosphorus concentrations are generally associated with elevated microscopic plant growth (measured as chlorophyll *a*). However, the chlorophyll *a* concentrations measured around Long Island were generally low during the summer months and suggest low to moderate phosphorus concentrations during that span. The high phosphorus concentration documented on September 11 should therefore be interpreted with caution as the chlorophyll *a* datum does not support an excessive total phosphorus concentration at that time. Future total phosphorus sampling will continue to examine this phenomenon. However, if problem areas are suspected we can focus increased efforts on these potentially problematic locations.

5) Long Island's resistance to acidification (measured as total alkalinity) was low in 1995, 6.5 units, and near the average of 6.6 units for **LLMP** program lakes. The 1995 seasonal average Long Island alkalinity matched the 1994 seasonal average alkalinity of 6.5 units and remained sufficient to buffer against acid loadings. Supplemental pH measurements, collected by the **FBG** on July 25, 1995, ranged from 6.9 to 7.2 units which is well within the tolerable range for most aquatic organisms.

6) Dissolved salt levels (measured as specific conductivity) were low at the Long Island deep sampling stations, Site 49 (range: 60.6 to 62.3 micro Siemans; υS) and Site 64 (range: 61.0 to 61.3 υS). High conductivity levels can be an indication of problem areas in the watershed where road salt runoff, excessive fertilizer applications, failing septic systems and other human activities are contributing contaminants into the lake.

7) Temperature profiles collected by the Long Island volunteer monitors indicate the upper mixed layer of water (epilimnion) extended to about 8.5 meters (28.1 feet) during the 1995 sampling season. The formation of temperature stratification limits water circulation and can favor oxygen depletion (anoxia) in the deeper waters (hypolimnion) as decaying vegetative materials accumulate along the lakebottom. Dissolved oxygen data collected by the **FBG** on July 25, 1995 indicate the

dissolved oxygen concentrations remained above 5 milligrams per liter (generally considered the minimum dissolved oxygen concentration necessary for the successful growth and reproduction of most coldwater fish) down to the lakebottom of each site sampled; Sites 45, 49 and 64 (Figures 33 and 34). The high dissolved oxygen concentrations throughout the water column were sufficient to sustain the cold water fish population and were sufficient to prevent internal nutrient loading (a phenomenon during which nutrients are released from the bottom sediments as the dissolved oxygen concentrations become depleted).

8) Based on the current and historical data, Lake Winnipesaukee-Long Island would be considered an unproductive New Hampshire lake. However, as in previous years, Site 49 continued to exhibit higher chlorophyll *a* and total phosphorus concentrations, as well as, lower water transparencies, relative to the other Long Island sampling stations (i.e. Site 49 is more productive than the other deep Long Island sampling stations).

COMMENTS AND RECOMMENDATIONS

1) We recommend that each participating association, including the Long Island Landowner's Association, continue to develop its data base on lake water quality through continuation of the long-term monitoring program. The data base currently provides information on the short and long-term cyclic variability that occurs around Long Island and through continued monitoring will enable more reliable predictions of water quality trends.

2) Changing land use within the Long Island watershed, the surrounding land that drains into the lake, can accelerate the natural aging process. A typical lake fills in and becomes more productive on a geological time frame (thousands of years), however, this process can be accelerated and occur in tens of years when development, agriculture and other landscape changes occur that do not incorporate best management practices (i.e. maintaining vegetative buffer strips along the shoreline, minimizing fertilizer and pesticide applications, installing proper erosion control structures, etc.) that are set up to minimize water quality impacts. We invite interested persons to take part in a new assessment manual, produced jointly by the **UNH LLMP** and the U S Natural Resource Conservation Service **(US NRCS)**, which provides the layperson with a systematic method for recognizing and evaluating erosion, sedimentation and related nonpoint source (NPS) pollutant problems in New Hampshire watersheds. With the current trend of increased development and land sales in New Hampshire such a survey is highly recommended. Contact the **LLMP** coordinator for further information.

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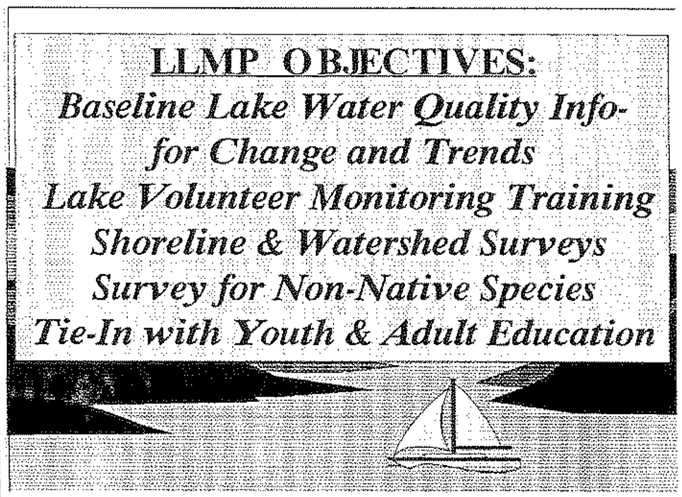
INTRODUCTION

The New Hampshire Lakes Lay Monitoring Program

1995 marked the eighteenth year of operation for the **NH Lakes Lay Monitoring Program (LLMP).** The **LLMP** has grown from a university class project on Chocorua Lake and pilot study on the Squam Lakes to a comprehensive state-wide program with over 500 volunteer monitors and more than 100 lakes participating. Originally developed to establish a data-base for determining long-term trends of lake water quality for science and management, the program has expanded by taking advantage of the many resources that citizen monitors can provide (Figure 1).

Figure 1. LLMP Objectives



The **NH LLMP** has an international reputation as a successful cooperative monitoring, education and research program. Current projects include: use of volunteer generated data for non-point pollution studies using high tech analysis system (Geographic Information Systems and Satellite Remote Sensing), intensive watershed monitoring for the development of lake nutrient budgets, and investigations of water quality and indicator organisms (food web analysis, fish condition, and stream invertebrates). The key ingredients responsible for the success of the program include innovative costshare funding and cost reduction, assurance of credible data, practical sampling protocols and, most importantly, the interest and motivation of our volunteer monitors.

The 1995 sampling season was another exciting year for the **New Hampshire Lakes Lay Monitoring Program**. National recognition for the high quality of work by you, the volunteer monitors, continued with awards, requests for program information and invitations to speak at national conferences (Figure 2).

Our work with volunteer monitor data incorporated into Geographic Information System technology was covered the spring '95 issue of the Volunteer Monitor Newsletter of which we were co-editors. The new Watershed Evaluation System for non-point source pollution (NPS Pollution) was field tested by our Wentworth and Winnipesaukee monitors and has been presented at meetings and conferences across the country. We completed a long-term trend study of selected areas of Lake Winnipesaukee utilizing a decade of data collected by our **NH LLMP** volunteers, for the Lakes Region Planning Commission, which was published as part of the Winnipesaukee Watershed Project. Working with teachers at Salem High School we incorporated

Figure 2. Awards & Recognition

AWARDS

and

1983- N H Environmental Law Council
1984- Governor's Volunteerism Award
1985- CNN Science & Technology Today
1988- Governor's "Gift" request funded
1990- New Hampshire Journal
1991- Renew America Success Award
Environmental Success Index
UN Environmental Programme
Soviet Embassy Reception
White House Environment Breifing
1992- EPA Administrators Award
Environmental Exchange Network
1993- NH Lakes Association
1994- Fourth National Citizens' Volunteer Monitoring Conference
EPA Office of Watersheds Award
1995- Co-editors Volunteer Monitor Newsletter (Spring Issue)
Winnipesaukee Watershed Project

students into a watershed protection study of Canobie Lake. The results of this project were quite astounding with students preparing posters and informational materials for their neighbors, for the Salem town meeting and for a special presentation to local officials.

On the local front, the NH Senate Agricultural and Environment committee and the NH House Resource, Recreation and Development Committee were again briefed on **NH LLMP** activities. We continue to be listed as a model citizen monitoring program on the Environmental Success Index of Renew America and on the Environmental Network Clearinghouse and were recently acknowledged by the National Awards Council for Environmental Sustainability. To date, the approach and methods of the **NH LLMP** have been adopted by new or existing programs in twenty two states and ten countries (Figure 3)!

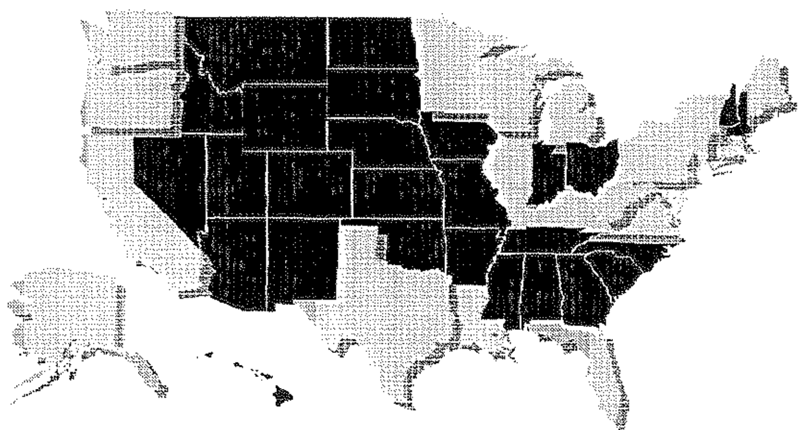
Importance of Long-term Monitoring

A major goal of a monitoring program is to identify any short or long-term changes in the water quality of the lake. Of major concern is the detection of cultural eutrophication: increases in the productivity of the lake, the amount of algae and plant growth, due to the addition of nutrients from human activities. Changes in the natural buffering capacity of the lakes in the program is also a topic of great concern, as New Hampshire receives large amounts of acid precipitation, yet most of our lakes contain little mineral content to neutralize this type of pollution.

For almost two decades, weekly

Figure 3. National LLMP Support to Volunteer Monitoring Programs

NH LLMP Directly inolved with the Initiation, Expansion or Support of Volunteer Programs in 22 States.



Light gray shading denotes LLMP assisted states

data collected from lakes participating in the **New Hampshire Lakes Lay Monitoring Program** have indicated there is quite a variation in water quality indicators through the open water season (April through November) on the majority of lakes. Short-term differences may be due to variations in weather, lake use, or other chance events. Monthly sampling of a lake during a single summer provides some useful information, but there is a greater chance that important short-term events such as algal blooms or the lake's response to storm run-off will be missed. These short-term fluctuations may be unrelated to the actual long-term trend of a lake or they may be indicative of the changing status or "health" of a lake.

Consider the hypothetical data depicted in Figure 4. Sampling only once a year during August from 1988 to 1992 produced a plot suggesting a decrease in eutrophication. However, the actual long-term term trend of the lake, increasing eutrophy, can only be clearly discerned by frequent sampling over a ten year period (Figure 5). In this instance, the information necessary to distinguish between short-term fluctuations "noise" and long-term trends "signal" was only manageable through the frequent collection of water quality data over many years. To that end, the establishment of a long term database was essential to trend detection in our hypothetical lake.

The number of seasons it takes to distinguish between the noise and the signal is not the same for each lake. Evaluation and interpretation of a long-term data base will indicate that the water quality of the lake has worsened,

Figure 4.

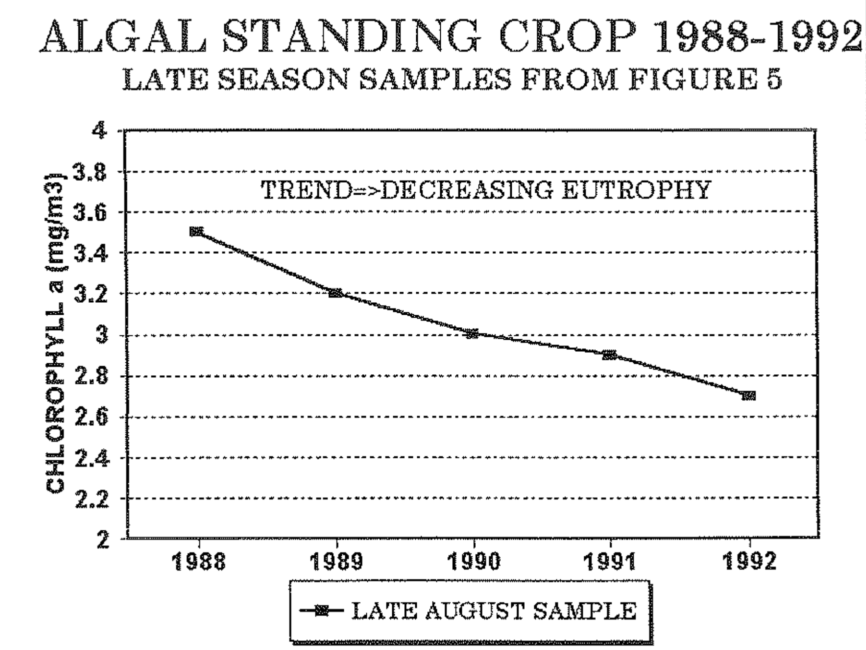
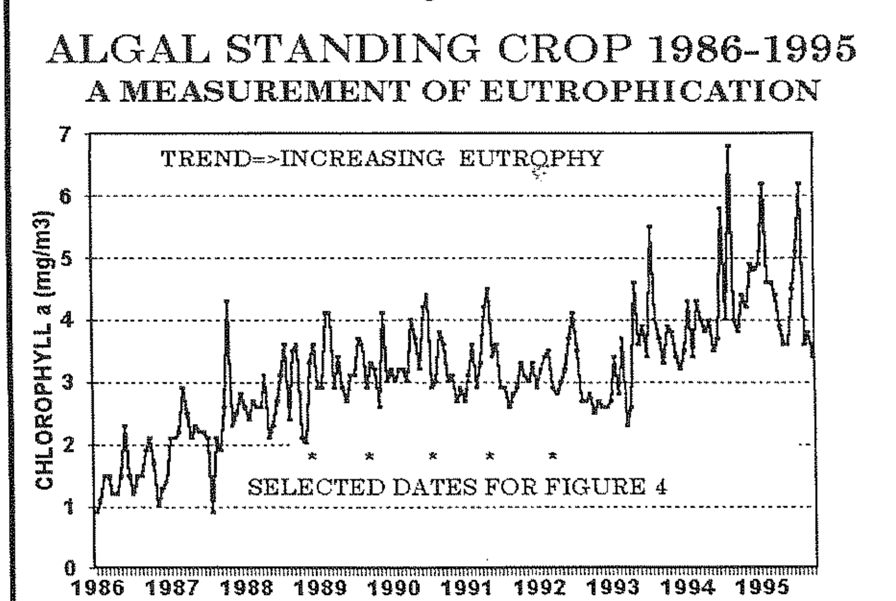


Figure 5.



improved, or remained the same. In addition, different areas of a lake may show a different response. As more data are collected, prediction of current and future trends can be made. No matter what the outcome, this information is essential for the intelligent management of the lake.

There are also short-term uses for lay monitoring data. The examination of different stations in a lake can disclose the location of specific problems and corrective action can be initiated to handle the situation before it becomes more serious. On a lighter note, some associations post their weekly data for use in determining the best depths for finding fish!

It takes a considerable amount of effort as well as a deep concern for one's lake to be a lay monitor in the **NH Lakes Lay Monitoring Program.** Many times a monitor has to brave inclement weather or heavy boat traffic to collect samples. Sometimes it even may seem that one week's data is just the same as the next week's data. Yet every sampling provides important information on the variability of the lake.

We are pleased with the interest and commitment of our Lay Monitors and are proud that their work is what makes the **NH LLMP** the most extensive, and we believe, the best volunteer program of its kind.

Purpose and Scope of This Study

1995 was the thirteenth year that water quality monitoring of Long Island was undertaken by the **Freshwater Biology Group** and the Long Island Landowner's Association. The monitoring program was designed to continue adding data to the long-term data base established. Sampling emphasis was placed on four open water deep sampling stations; Site 45 Ese Li., Site 49 Green's Boathouse, Site 61 West End and Site 64 Jonathan's Landing (Figure 10).

The primary purpose of this report is to discuss results of the 1995 monitoring season with emphasis on current conditions of Long Island including the extent of eutrophication and the lake's susceptibility to increasing acid precipitation. This information is part of a large data base of historical and more recent data compiled and entered onto computer files for New Hampshire lakes that include New Hampshire Fish and Game surveys of the 1930's, the surveys conducted by the New Hampshire Water Supply and Pollution Control Commission and the **FBG** surveys. However, care must be taken when comparing current results with early studies. Many complications arise due to methodological differences of the various analytical facilities and technological improvements in testing.

The General Scenario - 1995

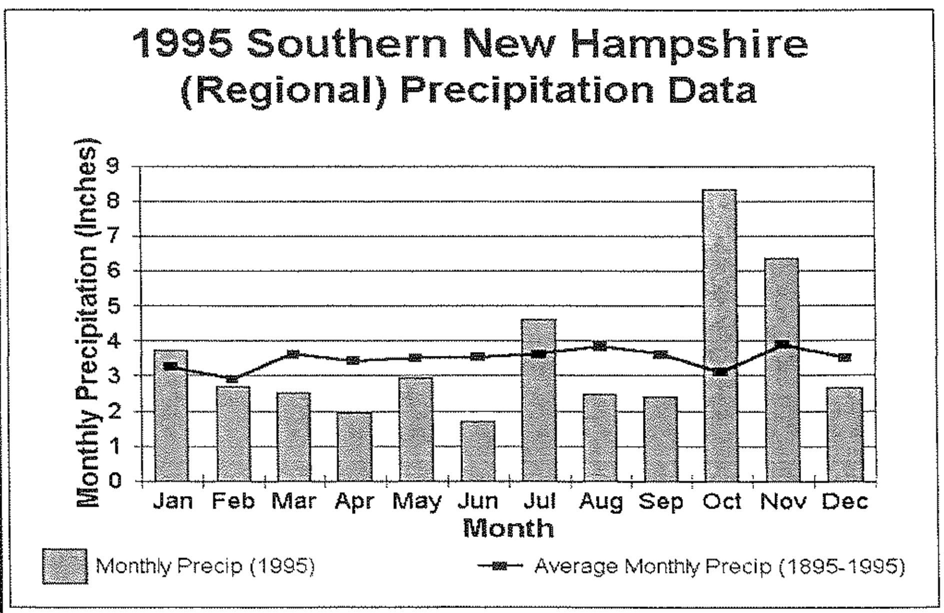
1995 Climatic Summary

The winter months of 1994-95 were characterized by above average temperatures and near to below average precipitation levels in Southern New Hampshire. Much of the precipitation was in the form of rainfall early in 1995 which minimized snowpack accumulation. The minimal snowpack accumulation and the below average precipitation levels during the spring months resulted in a relatively dry spring. Conditions such as these typically favor higher alkalinities (buffering capacities) and higher pH levels in the tributary streams and in our New Hampshire lakes as acidic spring runoff is minimized.

Below average rainfall continued to characterize southern New Hampshire into the spring months with precipitation levels over one inch below the historical average (1895-1995) during the months of March, April and June while the month of May was characterized by precipitation levels near one-half inch below the historical average (Figure 6). The summer was off to a wet start with 4.6 inches of rainfall during the month of July which exceeded the normal by about one inch. However, the months of August and September were again plagued by "drought" conditions with the precipitation levels over one inch below the historical average. The pattern of below average precipitation levels abruptly changed during the fall months of October and November with precipitation levels exceeding the historical monthly average precipitation levels by over two inches. In general, the 1995 Southern New Hampshire precipitation levels (through September) were well below normal while short-term wet spells were encountered; particularly in July. Note: While the general precipitation scenario, described above, summarizes the 1995 precipitation data for southern New Hampshire, the locality of daily precipitation events was highly variable and might not characterize the conditions around your lake.

Monthly precipitation levels in

Figure 6.



northern New Hampshire were lower than those in southern New Hampshire and culminated in severe drought conditions in northern New Hampshire during the summer months (Figure 7).

The 1995 temperature patterns also had an effect on water quality. The above average temperatures during much of January, February and March minimized snowpack retention and in turn minimized the corresponding spring runoff previously discussed (Figure 8). The temperatures were more characteristic of normal conditions in April and May while the months of June and July were again characterized by above average temperatures. The above average temperatures in June resulted in the rapid surface water (epilimnetic) warming which is conducive to algal, aquatic plant and bacterial growth.

Figure 7.

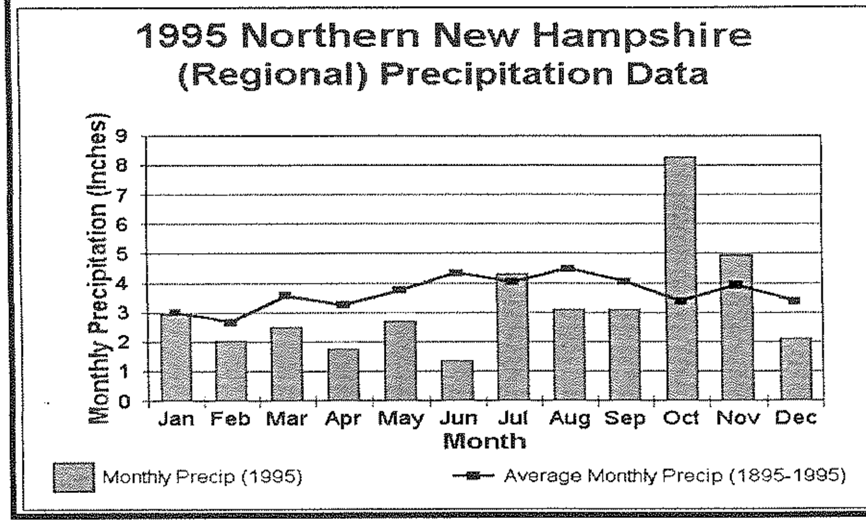
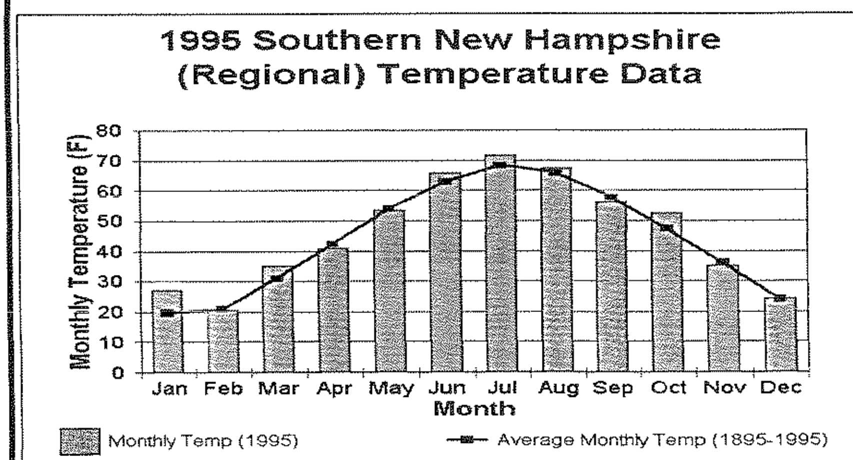


Figure 8.



Additional factors favoring localized algal, aquatic plant and bacterial growth included greater sunlight penetration during clear days, lower lake levels during the dry summer months, as well as, the mobilization of deep-water algal populations into the surface waters and increased growth rates during optimal conditions (discussed below). The above average temperatures, conducive to primary productivity, persisted through July but dipped to near average levels in August and resulted in surface water cooling in our New Hampshire lakes which continued into the fall months.

1995 Water Quality Observations

Higher Secchi Disk transparency readings, relative to 1994, were characteristic of most New Hampshire Lakes during the 1995 sampling season. Deep lake sampling stations were clearer due to a combination of factors associated with the atypically dry summer months. Less dissolved colored compounds (dissolved organic matter from the breakdown of vegetation and soils) were washed in from surrounding forest and wetland areas. Dissolved water color is not indicative of water quality problems (although large increases in dissolved color sometimes follow large land clearing operations) but in some of our more pristine program lakes, it nevertheless has a large effect on water clarity changes. Reduced nutrient loadings from the land surface (lawns, roads, fields, etc.) favored low algal growth.

As with dissolved color and nutrients, the dry spring reduced the sediment and suspended matter load to many of our lakes and streams during that period while continued dry conditions through most of the summer continued to minimize sediment loading.

If Increased clarity was not the result of less dissolved color or chlorophyll *a* concentrations than it was likely due to less suspended sediment by default. To find out how these water quality indicators inter-relate for the Long Island deep sampling stations, compare the Secchi Disk, chlorophyll *a* and dissolved color graphs enclosed in this report (Figures 11 through 22). Note whether changes in clarity (Secchi Disk depth) correspond to chlorophyll *a* or dissolved color concentration changes or whether it is a combination of the two. If neither seem to exhibit a consistent effect, then suspended sediment likely plays an important role in your lake's clarity.

However, during warm summers such as 1995, microbiological populations can have an increased effect on the water clarity. In general, bacterial populations tend to persist longer and at higher densities as temperatures increase. This occurrence is not necessarily indicative of water quality problems as the majority of these organisms occur naturally and function to recycle materials throughout the lake (heterotrophic bacteria). Many of our monitors reported longer sample filtration times in 1995 yet no apparent increase in the appearance of algae on their filters. Heterotrophic bacteria were the most likely culprits in these cases. Large concentrations of these minute organisms can have a profound effect on water clarity as they can rapidly absorb and redirect light which will in turn diminish our Secchi Disk readings.

These same climatic conditions, however, also favor the longevity of disease causing pathogenic organisms. If cases of ear infections, stomach problems or other sickness were more prevalent this past summer it would be a good idea to incorporate microbiological (bacteria) testing into future monitoring efforts (see Discussion section).

Most lakes experienced "algal blooms" during the 1995 sampling season. "Algal blooms" are often "green water events" associated with decreases in water clarity due to their ability to absorb and scatter light within the water column, but can also accumulate near the lake bottom in shallow areas as "mats" or on the water surface as "scums" and "clouds". All types of "algal blooms" were observed in several participating **LLMP** lakes in 1995. The occasional formation of certain "algal blooms" are naturally occurring phenomenon and are not necessarily associated with changes in lake productivity. However, increases in the occurrence of "bloom" conditions can be a sign of eutrophication (the "greening" of a lake). Algal blooms of varied extent typically occur even in our most pristine lakes late in the fall and early in the spring as a result of lake mixing, which resuspends nutrients, at those times.

In most participating **NH LLMP** lakes, particularly during the months of July and August, cotton-candy like "clouds" of the nuisance green filamentous algae, *Mougeotia*, or a related species were observed. These algal forms often develop within nearshore weed beds where they can be seen along the lakebottom. Sometimes "clouds" are observed drifting freely into shallow areas around the lake. These algae often take advantage of nutrients that leak from particularly active submerged weeds or from bottom areas that have been disturbed by weed removal or other activities.

Mougeotia and related algal forms (*Spirogyra* and *Zygenema*) flourished in 1995. The above average temperatures and a number of bright and sunny days during the months of June, July and August stimulated macroscopic plant growth that in turn provided optimal habitat and conditions for the growth of filamentous algal "clouds". While increased growth of *Mougeotia* and the related forms is often perceived as an indication of declining water quality, the 1995 algal populations are more likely attributable to the natural weather conditions that characterized 1995. Elevated macroscopic plant and elevated filamentous algal growth were documented in lakes ranging from unproductive, pristine systems, to those lakes typically considered highly productive and suggest a naturally occurring, short term, climatological impact upon our New Hampshire lakes. If this is true, reduced macroscopic plant and filamentous algal growth should characterize future summers which demonstrate more normal temperature patterns (cooler temperatures and more typical precipitation).

For a limited number of lakes, weather conditions became conducive to the formation of "blooms" of other algae species during the summer months when the water temperatures were above average. Unlike 1993, when the algal blooms were short-term events (spanning less than a week), the blooms persisted for greater than a month in a handful of sampled lakes. In those lakes which experienced long-term algal blooms the types of algae tended to be of the nuisance blue-green bacterial variety (formerly referred to as blue-green algae) and included such nuisance forms as *Anabaena, Lyngbya, Merismopedia* and *Oscillatoria.*

In other lakes, metalimnetic algae, algae which tend to grow in a thin layer along the thermocline gradient in a lake's middle depths, sometimes migrate up towards the lake surface causing a "bloom" event. If these algae are predominantly "nuisance" forms, like certain green or blue-green algae, they can be an early indication nutrient loading. The **LLMP** will continue to monitor "bloom" phenomenon in 1996 as it can be a sign of the changing land use practices and impacts within the lake watershed that can result in a long-term increase in lake productivity. Future monitoring will continue to monitor the frequency of algal blooms in our New Hampshire lakes' and discern whether or not they are signs of short-term perturbations in water quality, the "noise" within the true long-term signal, induced by the weather conditions of this past summer.

DISCUSSION OF LAKE AND STREAM MONITORING MEASUREMENTS

The section below details the important concepts involved for the various testing procedures used in the **New Hampshire Lakes Lay Monitoring Program**. Where appropriate, summary statistics of 1995 results from all participating lakes are included. Certain tests or sampling performed at the time of the optional **Freshwater Biology Group** field trip are indicated by an asterisk (*).

Thermal Stratification in the Deep Water Sites

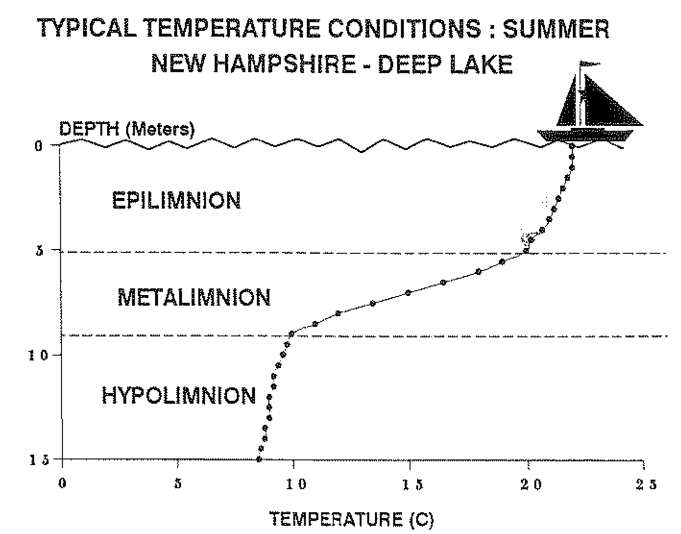
Lakes in New Hampshire display distinct patterns of temperature stratification, that develop as the summer months progress, where a layer of warmer water (the **epilimnion**) overlies a deeper layer of cold water (**hypolimnion**). The layer that separates the two regions characterized by a sharp drop in temperature with depth is called the **thermocline** or **metalimnion** (figure 9). Some shallow lakes may be continually mixed by wind action and will never stratify. Other lakes may only contain a developed epilimnion and metalimnion.

Water Transparency

Secchi Disk depth is a measure of the water transparency. The deeper the depth of Secchi Disk disappearance, the more transparent the lake water; light penetrates deeper if there is little dissolved and/or particulate matter (which includes both living and non-living particles) to absorb and scatter it.

In the shallow areas of many lakes, the Secchi Disk will hit bottom before it is able to disappear from view (what is referred to as a "Bottom Out" condition). Thus, Secchi Disk measurements are generally taken over the deepest sites of a lake. Transparency values greater than 4 meters are typical of clear, unproductive lakes while transparency values less than 2.5 meters are generally an indication of highly productive lakes. Water transparency values between 2.5 meters and 4 meters are generally considered indicative of moderately productive lakes.

Figure 9



In 1995 the average transparency for lakes participating in the **NH LLMP** was 5.6 meters with a range of 0.6 to 12.7 meters. Table 1 summarizes the 1995 Long Island Secchi Disk transparency data while a more complete summary of the current and historical Secchi Disk data is included in Appendix A.

Table 1. 1995 Lay Monitor Secchi Disk Data comparison of the Long Island deep sampling stations.

Site	Transparency (m) Minimum	Transparency (m) Average	Transparency (m) Maximum	Sample Size
45 Ese Li	7.3	8.6	10.0	15
49 Green's	6.0	7.4	8.6	18
61 West Poin	6.5	8.7	10.4	14
64 John Ldg	7.0	8.7	10.7	14

Chlorophyll *a*

The chlorophyll *a* concentration is a measurement of the standing crop of phytoplankton and is often used to classify lakes into categories of productivity called trophic states. **Eutrophic** lakes are highly productive with large concentrations of algae and aquatic plants due to nutrient enrichment. Characteristics include accumulated organic matter in the lake basin and lower dissolved oxygen in the bottom waters. Summer chlorophyll *a* concentrations average above 7 mg m^3 (7 milligrams per cubic meter; 7 parts per billion). **Oligotrophic** lakes have low productivity and low nutrient levels and average summer chlorophyll *a* concentrations are generally less than 3 mg m^3. These lakes generally have cleaner bottoms and high dissolved oxygen levels throughout. **Mesotrophic** lakes are intermediate in productivity with concentrations of chlorophyll *a* generally between 3 mg m^3 and 7 mg m^3. In 1995, the average chlorophyll *a* concentration for lakes participating in the **NH LLMP** was 2.4 mg m^3 with a range of 0.2 to 24.9 mg m^3. Table 2 summarizes the 1995 Long Island chlorophyll *a* data while a more complete summary of the current and historical chlorophyll *a* data is included in Appendix A.

Table 2. 1995 Lay Monitor Chlorophyll *a* Data comparison of the Long Island deep sampling stations.

Site	Chl *a* (ppb) Minimum	Chl *a* (ppb) Average	Chl *a* (ppb) Maximum	Sample Size
45 Ese Li	0.9	1.5	2.1	8
49 Green's	0.9	1.7	3.9	9
61 West Pt	0.8	1.2	2.4	8
64 John Ldg	0.8	1.4	1.9	8

Testing is sometimes done to check for **metalimnetic algal populations**, algae that layer out at the thermocline and generally go undetected if only epilimnetic (point or integrated) sampling is undertaken. Chlorophyll concentrations of a water sample collected in the thermocline is compared to the integrated epilimnetic sample. Greater chlorophyll levels of the point sample, in conjunction with microscopic examination of the samples (see Phytoplankton section below), confirm the presence of such a population of algae. These populations should be monitored as they may be an indication of increased nutrient loading into the lake.

Turbidity *

Turbidity is a measure of suspended material in the water column such as sediments and planktonic organisms. The greater the turbidity of a given water body the lower the Secchi Disk transparency and the greater the amount of particulate matter present.

Turbidity is measured as nephelometric turbidity units (NTU), a standardized method among researchers. Turbidity levels are generally low in New Hampshire reflecting the pristine condition of the majority of our lakes and ponds. Increasing turbidity values can be an indication of increasing lake productivity or can reflect improper land use practices within the watershed which destabilize the surrounding landscape and allow sediment flushing into the lake.

While Secchi Disk measurements will integrate the clarity of the water column from the surface waters down to the depth of disappearance, turbidity measurements are collected at discrete depths from the surface down to the lakebottom. Such discrete sampling can identify layering algal populations (previously discussed) that are undetectable when measuring Secchi Disk transparency alone.

Dissolved Color

The dissolved color of lakes is generally due to dissolved organic matter from **humic substances**, which are naturally-occurring polyphenolic compounds leached from decayed vegetation. Highly colored or "stained" lakes have a "tea" color. Such substances generally do not threaten water quality except as they diminish sunlight penetration into deep waters. Increases in dissolved watercolor can be an indication of increased development within the watershed as many land clearing activities (construction, deforestation, and the resulting increased run-off) add additional organic material to lakes. Natural fluctuations of dissolved color occur when storm events increase drainage from wetlands areas within the watershed. As suspended sediment is a difficult and expensive test to undertake, both dissolved color and chlorophyll information is important when interpreting the Secchi Disk transparency

Dissolved color is measured on a comparative scale that uses standard chloroplatinate dyes and is designated as a color unit or ptu. Lakes with color below 10 ptu are very clear, 10 to 20 ptu are slightly colored, 20 to 40 ptu are lightly tea colored, 40 to 80 ptu are tea colored and greater than 80 ptu indicates highly colored waters. Generally the majority of New Hampshire lakes have color between 20 to 30 ptu. In 1995 the average dissolved color for participating **NH LLMP** lakes was 21.9 ptu with a range of 0.9 to 94.5 ptu. Table 3 summarizes the 1995 Long Island dissolved color data while a more complete summary of the 1995 dissolved color data is included in Appendix A.

Table 3. 1995 Lay Monitor Dissolved Color Data comparison of the Long Island deep sampling stations.

Site	Color (ptu) Minimum	Color (ptu) Average	Color (ptu) Maximum	Sample Size
45 Ese Li	6.0	10.5	17.2	8
49 Green's	5.2	9.4	11.2	8
61 West Pt	4.3	7.2	8.6	8
64 John Ldg	5.2	7.4	10.3	8

Total Phosphorus

Of the two "nutrients" most important to the growth of aquatic plants, nitrogen and phosphorus, it is generally observed that phosphorus is the more limiting to plant growth, and therefore the more important to monitor and control. Phosphorus is generally present in lower concentrations, and its sources arise primarily through human related activity in a watershed. Nitrogen can be fixed from the atmosphere by many bloom-forming blue-green bacteria, and thus it is difficult to control. The total phosphorus includes all dissolved phosphorus as well as phosphorus contained in or adhered to suspended particulates such as sediment and plankton. As little as 15 parts per billion of phosphorus in a lake can cause an algal bloom.

Generally, in the more pristine lakes, phosphorus values are higher after spring melt when the lake receives the majority of runoff from its surrounding watershed. The nutrient is used by the algae and plants which in turn die and sink to the lake bottom causing surface water phosphorus concentrations to decrease as the summer progresses. Lakes with nutrient loading from human activities and sources (Agriculture, Logging, Sediment Erosion, Septic Systems, etc.) will show greater concentrations of nutrients as the summer progresses or after major storm events.

Streamflow

Streamflow is a measure of the volume of water traversing a given stream stretch over a period of time and is often expressed as cubic meters per second. Knowledge of the streamflow is important when determining the amount of nutrients and other contaminants that enter a lake. Knowledge of the streamflow in conjunction with nutrient concentrations, for instance, will provide the information necessary to calculate phosphorus loading values and will in turn be useful in discerning the more impacted areas within a watershed.

pH *

The pH is a way of expressing the acidic level of lake water, and is generally measured with an electrical probe sensitive to hydrogen ion activity. The pH scale has a range of 1 (very acidic) to 14 (very "basic" or alkaline) and is logarithmic (i.e.: changes in 1 pH unit reflect a ten times difference in hydrogen ion concentration). Most aquatic organisms tolerate a limited range of pH and most fish species require a pH of 5.5 or higher for successful growth and reproduction.

Alkalinity

Alkalinity is a measure of the buffering capacity of the lake water. The higher the value the more acid that can be neutralized. Typically lakes in New Hampshire have low alkalinities due to the absence of carbonates and other natural buffering minerals in the bedrock and soils of lake watersheds.

Decreasing alkalinity over a period of a few years can have serious effects on the lake ecosystem. In a study on an experimental acidified lake in Canada by Schindler, gradual lowering of the pH from 6.8 to 5.0 in an 8-year period resulted in the disappearance of some aquatic species, an increase in nuisance species of algae and a decline in the condition and reproduction rate of fish. During the first year of Schindler's study the pH remained unchanged while the alkalinity declined to 20 percent of the pre-treatment value. The decline in alkalinity was sufficient to trigger the disappearance of zooplankton species, which in turn caused a decline in the "condition" of fish species that fed on the zooplankton.

The analysis of alkalinity employed by the **Freshwater Biology Group** includes use of a dilute titrant allowing an order of magnitude greater sensitivity and precision than the standard method. Two endpoints are recorded during each analysis. The first endpoint (gray color of dye; pH endpoint of 5.1) approximates low level alkalinity values, while the second endpoint (pink dye color; pH endpoint of 4.6) approximates the alkalinity values recorded historically, such as NH Fish and Game data, with the methyl-orange endpoint method.

The average alkalinity of lakes throughout New Hampshire is low, approximately 6.5 mg per liter (calcium carbonate alkalinity). When alkalinity falls below 2 mg per liter the pH of waters can greatly fluctuate. Alkalinity levels are most critical in the spring when acid loadings from snowmelt and run-off are high, and many aquatic species are in their early, and most susceptible, stages of their life cycle.

Specific Conductivity *

The specific conductance of a water sample indicates concentrations of dissolved salts. Leaking septic systems and deicing salt runoff from highways can cause high conductivity values. Fertilizers and other pollutants can also increase the conductivity of the water. Conductivity is measured in micro**mhos** (the opposite of the measurement of resistance **ohms**) per centimeter, more commonly referred to as micro-Siemans (υS).

Dissolved Oxygen and Free Carbon Dioxide *

Oxygen is an essential component for the survival of aquatic life. Submergent plants and algae take in carbon dioxide and create oxygen through **photosynthesis** by day. **Respiration** by both animals and plants uses up oxygen continually and creates **carbon dioxide**. Dissolved oxygen profiles determine the extent of declining oxygen concentrations in the lower waters. High carbon dioxide values are indicative of low oxygen conditions and accumulating organic matter. For both gases, as the temperature of the water decreases, more gas can be dissolved in the water.

The typical pattern of clear, unproductive lakes is a slight decline in hypolimnetic oxygen as the summer progresses. Oxygen in the lower waters is important for maintaining a fit, reproducing, cold water fishery. Trout and salmon generally require oxygen concentrations above 5 mg per liter (parts per million) in the cool deep waters. On the other hand, carp and catfish can survive very low oxygen conditions. Oxygen above the lake bottom is important in limiting the release of nutrients from the sediments and minimizing the collection of undecomposed organic matter.

Bacteria, fungi and other **decomposers** in the bottom waters break down organic matter originating from the watershed or generated by the lake. This process uses up oxygen and produces carbon dioxide. In lakes where organic matter accumulation is high, oxygen depletion can occur. In highly stratified eutrophic lakes the entire hypolimnion can remain unoxygenated or **anaerobic** until fall mixing occurs.

The oxygen peaks occurring at surface and mid-lake depths during the day are quite common in many lakes. These characteristic **heterograde oxygen curves** are the result of the large amounts of oxygen, the by-product of photosynthesis, collecting in regions of high algal concentrations. If the peak occurs in the thermocline of the lake, metalimnetic algal populations (discussed above) may be present.

Underwater Light *

Underwater light available to photosynthetic organisms is measured with an **underwater photometer** which is much like the light meter of a camera (only waterproofed!). The **photic zone** of a lake is the volume of water capable of supporting photosynthesis. It is generally considered to be delineated by the water's surface and the depth that light is reduced to one percent surface iridescence by the absorption and scattering properties of the lake water. The one percent depth is sometimes termed the **compensation depth**. Knowledge of light penetration is important when considering lake productivity and in studies of submerged vegetation. Discontinuity (abrupt changes in the slope) of the profiles could be due to metalimnetic layering of algae or other particulates (discussed above). The underwater photometer allows the investigator to measure light at depths below the Secchi Disk depth to supplement the water clarity information.

Indicator Bacteria *

Certain disease causing organisms, pathogenic bacteria, viruses and parasites, can be spread through contact with polluted waters. Faulty septic systems, sewer leaks, combined sewer overflows and the illegal dumping of wastes from boats can contribute fecal material containing these pathogens. Typical water testing for pathogens involves the use of detecting coliform bacteria. These bacteria are not usually considered harmful themselves but they are relatively easy to detect and can be screened for quickly. Thus, they make good surrogates for the more difficult to detect pathogens.

Total coliform includes all coliform bacteria which arise from the gut of animals or from vegetative materials. **Fecal coliform** are those specific organisms that inhabit the gut of warm blooded animals. Another indicator organism **Fecal streptococcus** (sometimes referred to as **enterococcus**) also can be monitored. The ratio of fecal coliform to fecal strep may be useful in suggesting the type of animal source responsible for the contamination. In 1991, the State of New Hampshire changed the indicator organism of preference to <u>E. Coli</u> which is a specific type of fecal coliform bacteria thought to be a better indicator of human contamination. The new state standard requires Class A "bathing waters" to be under 88 organisms (referred to as colony forming units; cfu) per 100 milliliters of lakewater.

Ducks and geese are often a common cause of high concentrations of coliform at specific lake sites. While waterfowl are important components to the natural and aesthetic qualities of lakes that we all enjoy, it is poor management practice to encourage these birds by feeding them. The lake and surrounding area provides enough healthy and natural food for the birds and feeding them stale bread or crackers does nothing more than import additional nutrients into the lake and allows for increased plant growth. As birds also are a host to the parasite that causes "swimmers itch", waterfowl roosting areas offer a greater chance for infestation to occur. Thus while leaving offerings for our feathered friends is enticing, the results can prove to be detrimental to the lake system and to human health.

Phytoplankton *

The planktonic community includes microbial organisms that represent diverse life forms, containing photosynthetic as well as non-photosynthetic types, and including bacteria, algae, crustaceans and insect larvae (the insect larvae and zooplankton are discussed below in separate sections). Because planktonic algae or "phytoplankton" tend to undergo rapid seasonal cycles on a time scale of days and weeks, the levels of populations found should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

The composition and concentration of phytoplankton can be indicative of the trophic status of a lake. Seasonal patterns do occur and must be considered. For example **diatoms**, tend to be most abundant in April-June and October-November, in the surface or epilimnetic layers of New Hampshire lakes. As the summer progresses, the dominant types might shift to **green algae** or **golden algae**. By late season **Blue-green bacteria** generally dominate. In nutrient rich lakes, nuisance green algae and/or bluegreen bacteria might dominate continually. After fall mixing diatoms might again be found to bloom.

Zooplankton *

There are three groups of zooplankton that are generally prevalent in lakes: the **protozoa**, **rotifers** and **crustaceans**. Most research has been devoted to the last two groups although protozoa may be found in substantial amounts. Of the rotifers and the crustaceans, time and budgetary constraints usually make it necessary to sample only the larger zooplankton (macrozooplankton; larger than 80 or 150 microns; 1 million microns make up a meter). Thus, zooplankton analysis is generally restricted only to the larger crustaceans. Crustacean zooplankton are very sensitive to pollutants and are commonly used to indicate the presence of toxic substances in water. The crustaceans can be divided into two groups, the **cladocerans** (which include the "water fleas") and the **copepods**.

Macrozooplankton are an important component in the lake system. The filter feeding of the herbivorous ("grazing") species may control the population size of selected species of phytoplankton. The larger zooplankton can be an important food source for juvenile and adult planktivorous fish. All zooplankton play a part in the recycling of nutrients within the lake.

As discussed above for phytoplankton, zooplankton undergo seasonal population cycles and the results discussed below are most representative of the collection dates and not necessarily of other times during the ice-free season, especially during the early spring and late fall.

Macroinvertebrates *

Macroinvertebrates generally refer to the aquatic insect community living near the bottom substrate (i.e. sediments) while other invertebrate groups such as the crayfish, leeches and the aquatic worms are also included. Like the phytoplankton and zooplankton, previously discussed, the macroinvertebrates undergo seasonal cycles and are most representative of conditions for particular periods of the year. The mayflies are probably the most well known example of a seasonal aquatic macroinvertebrate as mayfly populations metamorphosize into adults as the water temperatures increase in the spring and thus giving rise to the name "mayflies". Macroinvertebrates are also sensitive to environmental conditions such as streamflow, temperature and food availability and are most representative of particular habitats along the stream continuum (i.e. some organisms prefer slower moving stream reaches while others prefer rapidly flowing waters).

Macroinvertebrates are an essential component to a healthy aquatic habitat. Macroinvertebrates help decompose organic matter entering the system such as leaves and twigs and also serve as a food source for many fish species.

While some macroinvertebrates are capable of breathing air as we do, others have gills and utilize oxygen dissolved in the water much as fish do. Macroinvertebrates also vary in their tolerance to depleting dissolved oxygen concentrations making them a good indicator of pollutants coming into the water body. The caddisflies (Trichoptera), the mayflies (Ephemeroptera) and the stoneflies (Plecoptera) are often considered highly sensitive to pollution while the "true" flies (Diptera) are often considered highly tolerant to pollution. However, exceptions to the above categorizations are often encountered.

A variety of indices have been proposed to characterize water bodies over a gradient of pollution levels ranging from least polluted to most polluted scenarios and often designated by assigning a numerical delineator (i.e. 1 is least polluted while 10 is most polluted). Such an index, the Hilsenhoff Biotic Index (HBI), or a modification thereof, is commonly used by stream monitoring programs around the country. Macroinvertebrate data are useful in discerning the more impacted areas within the watershed where corrective efforts should be directed. Unlike chemical measurements that represent ambient conditions in the water body, the macroinvertebrate community composition integrates the water quality conditions over a longer period (months to years) and can identify "hot" spots missed by chemical sampling. If you are interested in more information regarding macroinvertebrate monitoring contact the **LLMP** coordinator.

Fish Condition

The assessment of fish species "health" is another biological indicator of water quality. Because fish are at the top of the food chain, their condition should reflect not only water quality changes that affect them directly but also those changes that affect their food supply. The fish condition index utilized by the **New Hampshire Fish Condition Program** is based on two components; fish scale analysis and a fish condition index.

Like tree trunks, fish scales have annual growth rings (annuli) that reflect their growth history and hence, provide a long-term record of past conditions in the lake. The fish condition index, based upon length and weight measurements, is a good indicator of the fish's health at the time of collection.

The resulting fish condition data can be compared among different lakes or among different years, or the index for a particular species can be compared to standard length-to-weight relationships that have been developed by fisheries biologists for many important fish species. In the end, the "health" of the various fish species reflects the overall water quality in the respective lake or pond.

Zebra Mussels

Zebra mussels (*Dreissena polymorpha*) are non-native, freshwater mollusks. The veligers (larval form) are free swimming, nearly invisible, and profuse. Adult zebra mussel shells are elongate (D-shaped), about the size of a thumbnail and are usually striped. Zebra Mussels are the only freshwater mussel that can attach to objects using sticky threads (byssal threads like those found on the marine blue mussels). These threads allow them to colonize quickly and reach densities of 100,000 or more mussels per square yard. The mussels have an average lifespan of 3.5 to 5 years. A gritty feeling on your boat's hull or other immersed surfaces might indicate that larval zebra mussels have settled.

Zebra mussels originated in the drainage basins of the Black, Caspian, and Aral seas of eastern Europe and have been in western Europe freshwaters since the 1700s. Since first being introduced to North America in 1986, zebra mussels have dramatically altered the balance of freshwater systems and fisheries. These small water dwelling animals have also caused millions of dollars in expenses for industrial water users, drinking water facilities, commercial and recreational boaters, farmers, and other groups and organizations in Canada and the Great Lakes region.

The range occupied by these unwelcome visitors has expanded and continues to grow rapidly. In North America, sightings have been recorded as far north as the Saint Lawrence River near Quebec, as far east as the lower portion of the Hudson River, as far south as the Mississippi River near Vicksburg, and as far west as the Arkansas River in Oklahoma.

In 1993, zebra mussel sightings were confirmed in New England (Lake Champlain). The Lake Champlain population has existed for at least three years, if not longer. Thus, New Hampshire residents and boaters are being encouraged to arm themselves with knowledge about the natural history and geographic spread of the mussels. Interstate boaters and anglers, in particular, should become familiar with boating and fishing practices that decrease the likelihood that zebra mussels will be transferred from an infested water body to an uninfested one.

The infestation risk factor for any particular water body is determined mainly by the amount and type of boat traffic it supports and the chemical characteristics and temperature it maintains. While the goal is to prevent the mussels from becoming established in New England waters, zebra mussels have proven to be adaptable creatures able to survive in a growing range of environmental conditions. Cooperative monitoring activities coordinated by the **New Hampshire Lakes Lay Monitoring Program** will help determine if and when zebra mussels become established in this region. If zebra mussels are found, information about control techniques can help those concerned choose the best method to reduce the destructive impacts of the mussels.

Take responsibilities for our waters. If you've been boating in fresh water outside of New England within the past 10 days and plan to launch locally, please...

Inspect your boat and trailer for weeds. Remove and discard any you find. Zebra mussels are commonly found on aquatic plants in areas of infestation.

Flush the cooling system, bilge areas and live wells with tap water.

Leave unused bait behind and discard bait bucket water away from surface waters.

Keep your boat out of water to dry for 48 hours. If it is visibly fouled by algae, leave it out until the exterior is completely dry **or...**

Wash down the hull at a car wash. Hot (140 degree F) water kills zebra mussels and veligers and high pressure spray helps remove them. Wash fouling off your boat away from water sources!

Learn more about the zebra mussel threat in order to be forewarned of the situation and prevent costly repairs or destructive responses.

Share information, ideas and monitoring tasks with other members of your lake association, watershed council, marina club, conservation commission, angling group or civic organization.

Report any sightings to the **New Hampshire Lakes Lay Monitoring Program.** Preserve specimens in alcohol if possible, note the location where they were found, and send them in to confirm the identification.

To receive more information, request an educational presentation for your next group meeting, become involved in monitoring efforts, or confirm an identification, contact:

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Rainfall... People... and Lake Water Quality

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High quality lakes will always remain an invaluable attraction to people, thus an important element of New Hampshire's economy. Questions about changes in water quality and clarity are often asked. Now data which have been gathered by University of New Hampshire researchers, in cooperation with many volunteer monitors, are beginning to provide some answers to questions such as: *Have our lakes degraded in this century? Is water quality currently deteriorating? What is causing changes to occur?* Now we can begin to answer these questions.

Dynamic Lakes

In order to understand the answers, one must have some awareness of Limnology - the study of the geologic, physical, chemical and biological dynamics of lakes. It is important to be alert to the changing nature of lakes, their sensitivity to disturbances, and their likelihood to degrade or improve in quality in response to poor or good protection strategies.

It is possible to identify many characteristics that determine the uniqueness of each lake and help to distinguish a blue jewel from a septic waste depot. Volunteer monitors from the **N.H. Lay Lake Monitoring Program (LLMP)** have amassed data from more than 100 New Hampshire lake sites over the past decade. The objective of this effort, established in 1978, was to develop information to scientifically document long-term trends in water quality.

It is now possible to understand the kinds of disturbances that modify the characteristics of a lake for better or worse. This cooperative effort between lakeshore property owners and UNH researchers has established how lake water quality changes over the decades. Based upon accumulated data it is possible to use a model to predict these events.

The Overview

Although each New Hampshire lake is unique, and there is a diversity of lake types in the state, the **LLMP** data reveal a remarkably common pattern in the "behavior" of most lakes. Researches anticipated that multiple sites within any given lake would have the same characteristics. There is also strong evidence that large and small lakes follow a similar pattern of changes, within the ice-free period of a single year as well as through nearly two decades of observations. This is quite a surprise! *How can unique lakes in unique watershed "behave" in such a similar manner?*

The "long-term" changes in water quality characteristics are not always monotonously negative, but appear to fluctuate corresponding to 11-year cycles of solar flares or sunspots. What is the role of human behavior? There is no cyclic pattern to human activity on lakes.

*Why, for example, did Squam Lake become greener from 1979 through 1984, then suddenly clarify in 1985? Why did the clarity of nearly all lakes in the **LLMP** program improve in 1985? Why did the chlorophyll (the major pigment in microscopic plants) decrease significantly in the same year? Furthermore, why was total phosphorous in the water very low in 1985? Why was there a relatively high Acid Neutralizing Capacity in that year? (ANC is the capacity of a lake to absorb or buffer higher levels of acidity in the water). Finally, why have all these water quality parameters changed together in the reverse direction from 1986 to 1993?*

A few lakes have "misbehaved" and followed opposite trends during the same period, but this can be attributed to their unique characteristics, and to site-specific circumstances.

The Hunch

New Hampshire is a relatively small state. Despite other diversities, our lakes are all subjected to the climate we enjoy at 43° to 44° North latitude. The whimsical nature of New England weather, difficult to predict, variable from season to season and year to year, is well known. *Could it be that our lakes are responding to climatic variation and global warming? What was unique about 1985?*

A reasonable hunch was that changes in total rainfall could be the "pied piper" playing the tune to which the lakes have danced. A comparison of rainfall data from 30 National Oceanographic and Atmospheric Administration weather stations confirmed that the state is basically a single climate region. While rainfall is much higher in some areas than others, the pattern is similar no matter where one looks. A dry year is a dry year and a wet year is a wet year, statewide. The record rainfall between July 1984 and June 1985 occurred during a period of sub-normal rainfall relative to 30-year averages.

So! We have a clue.

The Model

The majority of New Hampshire's lakes are what is known as "nutrient limited." This means that certain nutrients, especially phosphorus and nitrogen, when present in lake water stimulate high levels of growth in microscopic aquatic plants such as algae and phytoplankton. Humans, along with other creatures, process these nutrients quickly and deposit them in lakes or in water flowing down a watershed.

In addition, most watersheds in New Hampshire are small and have steep topography. The streams within these watersheds are typically short and fast-flowing, delivering rainwater to lakes very quickly. Thus, episodes of high rainfall deliver more nutrients by washing them into lakes from watersheds. Prolonged periods (up to one year) of high rainfall lead to more nutrient loading and higher total phosphorus levels, therefore greener and less transparent lakes. In addition, sulfur dioxide in rainwater-- the ingredient that causes acid rain -- and solutes (dissolved acids) collected within the watershed, lowers the ANC of our lakes, i.e., the capacity of lakes to buffer the effects of acidity is diminished.

At its present state of development, the LLMP model suggests that the total volume of rainfall is the cause of both seasonal and long-term annual changes in lake water quality throughout New Hampshire. Most lakes "improved" in dry years such as 1985 and "degrade" in wetter years such as 1984 and 1986. The model works to the extent that the loading of nutrients into nutrient-deprived lakes is dependent on rainfall, and this appears to be the case.

Further verification of the model comes from the few more productive lakes, i.e., those higher in naturally occurring levels of nutrients. The "richer" in nutrients a lake, the "greener" it tends to be. Such "rich" lakes tend to be "diluted" by the loading of stormwater running off the watershed. This again directly implicates rainwater as the "piedpiper" which causes such lakes to be somewhat less productive, therefore "improved," during wet years.

Implications

At least two important predications can be developed when interpreting the LLMP model. First, changes in rainfall volume associated with global warming will influence lake water quality directly. If New Hampshire becomes drier, the lakes will tend to remain transparent and on that basis, will likely "improve" in water quality. Otherwise, a wetter future will likely deplete water quality to some extent.

Second, the model provides substantial evidence that our lakes are sensitive to changes in nutrient loading. Such loading can be controlled to a large extent by the choices people make with regard to activities within a watershed area. Such activities include land use and development patterns and practices within the watershed area, as well as along the shoreland areas of lakes and streams. Human activity on the water can also have some impact on nutrient loading of lakes (see Spring 1995 *Lakeside*).

Efforts to minimize nutrient loading can make a difference. Such practices as:

- routine pumping of septic systems
- erosion control
- maintaining buffer and wooded areas near lakes and within watershed
- control of storm water run-off from roof tops, impermeable driveways and parking lots

all help to minimize nutrient transport to lakes.

Future Concerns

While we can predict lake water quality parameters based upon weather patterns in a given year or over a period of years, there are a number of issues that require more comprehensive and thoughtful policy development if New Hampshire's lakes are going to remain the blue gems that we take for granted.

here are some of the unresolved issues:

- The survival of each lake given the multiple uses which they receive now, and will receive in the next millennium.
- The study of lake capacity, or use beyond which a lake becomes undesirable.
- The possibility that lakes will lose their aesthetic and economic value if they visibly degrade over time.
- The establishment of a comprehensive statewide lake use plan to manage our lakes effectively.

The Zebra Mussel Threat to New Hampshire

The Zebra Mussel, a non-native freshwater mollusk that has successfully invaded a host of lakes and rivers throughout northeastern and central North America, continues its expansion towards New Hampshire. In the past three years, primarily due to the efforts of state agencies like **New Hampshire Fish Game** and **New Hampshire Department of Environmental Services (DES)**, the New Hampshire Lakes Association as well as local lake associations, residents and visitors have started to become aware of this non-native aquatic nuisance. All of these groups have been assisted by the University of New Hampshire (UNH) SeaGrant and Water Resource Extension Programs of the Northern New England Mussel Watch.

These tenacious little shellfish have caused almost a billion dollars worth of trouble in the Great Lakes region of the US and Canada. More recently, they impacted water suppliers and a federal fish hatchery on Lake Champlain in neighboring Vermont to the tune of millions of dollars. Thus, there is great concern with this potential threat to New Hampshire's precious fresh waters. But given the fact that many lakes and streams have very soft waters (they contain low mineral content especially that of calcium which is important for reproduction and shell construction) how concerned should we be?

Table 4 breaks down the colonization potential of Zebra Mussels according to the water conditions they encounter. As can be seen, most of our fresh waters meet their

TABLE 4:
ZEBRA MUSSEL COLONIZATION POTENTIAL

Based on environmental tolerances of known wild and lab populations in Europe and North America

(modified from C. O'Neill, NY SeaGrant Zebra Mussel Clearing House 6/95)

Variable	High Potential	Moderate Potential	Low Potential	Very Low Potential	NH Summer Range *	NH Summer Average *
SALINITY (ppt)	0 - 1	1 - 4	4 - 10	10 - 35	none	less than 0
CALCIUM (mg/L)	> 25	20 -25	9 - 20	< 9	<1 - 32	3.4
pH (units)	7.4 - 8.5	7.0 - 7.4 8.5 - 9.0	6.5 -7.0	< 6.5 > 9.0	4.4 - 9.6	6.0
WATER TEMP. °C)	18 - 25	16 -18 25 -29	9 -15 28 - 30	< 8 > 30	9.8 - 30	varies by depth
DISSOLVED OXYGEN (ppm)	8 - 10	6 - 8	4 - 6	< 4	0 - 12	generally > 6 in upper layer
CONDUCTIVITY (umhos at 25°C)	> 83	37 - 82	22 - 36	< 21	13 - 350	55
CHLOROPHYLL	Greater than	2 ppb	CHL a	(algae level)	0.1 - 144	7.2

* Summer upper water (epilimnetic) layer data from UNH Freshwater Biology Group and NH DES Limnology Center data bases 1978 to 1993; total of 597 NH lakes sampled.

> = greater than; < = less than.

temperature, algae, salinity and oxygen requirements. Limiting colonization for a majority of our lakes is pH and calcium content. It is ironic that the conditions that hurt us most in combating acid rain impacts may be our saving grace in preventing dense colonies of mussels. Of the two parameters, calcium is the more critical in that the pH of even the softest waters can increase to more tolerable levels due to the photosynthetic activity of submerged plants and algae (the removal of carbon dioxide from the water raises the pH in dense weed beds and in more productive lakes).

Care must be taken in concluding how safe we really are from infestation. These data are only from known zebra mussel habitats. In the lab, zebra mussels have successfully reproduced at salinities as high as 15 parts per thousand. Also, the lower limit of the calcium requirement continues to fall with time.

So which of our waters are most susceptible to Zebra Mussel colonization? Table 5 lists those waters with calcium concentrations of 9 parts per million or greater. There are two lakes that have water conditions highly conducive to colonization, three lakes with moderate potential and at least 16 lakes with low potential (an additional 8 lakes have calcium levels just under 9 parts per million). Most are located somewhere near the Connecticut River that has limestone deposits that can contribute calcium to nearby waters. The others are in the lower Merrimack River valley. There are also some close to the sea coast. UNH Sea Grant has initiated monitoring for adult mussels on the majority of these lakes through existing **NH LLMP (UNH), VLAP (DES)** and Cooperative Extension/SeaGrant monitoring programs.

Table 5. Lakes Most Susceptible to Zebra Mussel Colonization.

Lake		Town
Horseshoe	(low risk)	Merrimack
Harris Pond		Pelham
Kimball Pond		Canterbury
Post Pond		Lyme
Sebbins Pond	(med. risk)	Bedford
Wilder Lake		Lebanon
Cobbetts Pond		Windham
Crystal Lake		Manchester
Ogontz Lake		Lyman
Moses Pond		Plainfield
Dorrs Pond		Manchester
World End Pond		Salem
Otternick Pond		Hudson
Fish Pond		Columbia
Flints Pond		Hollis
Taylor River		Hampton
Kendall Pond		Londonderry
Stevens Pond		Manchester
Lime Pond	(high risk)	Columbia
Mill Pond		Portsmouth

While our current understanding of the mussels may allow for a brief sigh of relief on the part of our low calcium lakes, boaters and anglers should still continue to take the proper precautions on <u>all</u> waters. We are still continuing to amass all of the available information and research on these persistent little shellfish. The most frightening information indicates that these critters are becoming more at home in a wider range of water conditions; the water conditions within the mussels American range are much wider than those found in the mussels native habitat in Central Europe. Zebra Mussels have only been in our country since sometime around 1988 while they have been known to occur in large freshwater lakes such as the Black, Caspian and Aral seas for hundreds if not thousands of years. This means that the invading mussels have been adapting quickly. Remember also that our native shellfish have adapted very well to our soft waters.

That is the reason zebra mussel warning signs have been posted with information posters and pamphlets at public areas and boat-launch sites. These materials are in place at lakes with higher calcium levels as well as high boat traffic areas. In addition, these precautions will minimize the risk of introducing non-native weeds like milfoil and other new plant and animal invaders that could eventually find a way into New Hampshire.

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REPORT FIGURES

Figure 10. Location of the 1995 Long Island deep sampling stations; Site 45 Ese Li, Site 49 Green's Boathouse, Site 61 West End and Site 64 Jonathan's Landing, Moultonborough, New Hampshire.

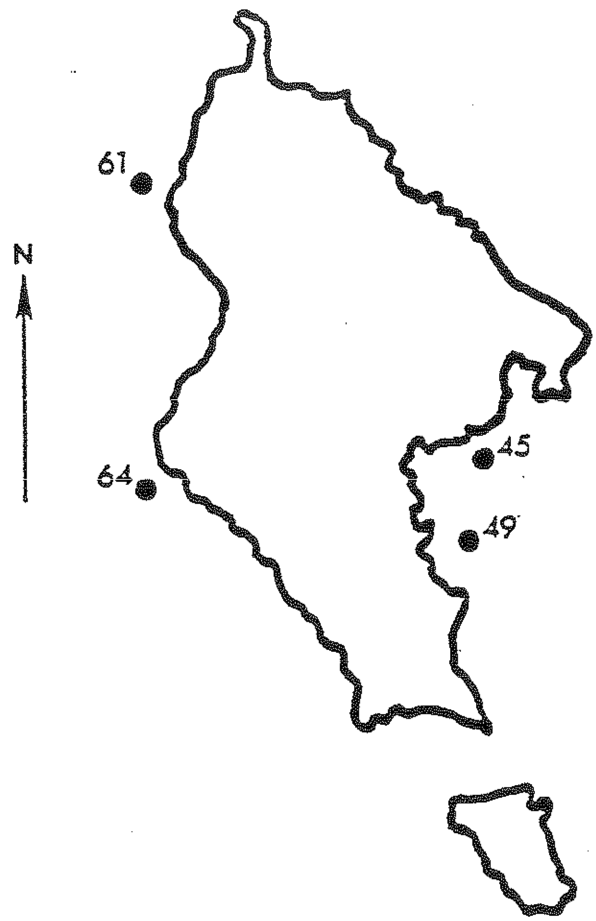

N
61
64
45
49

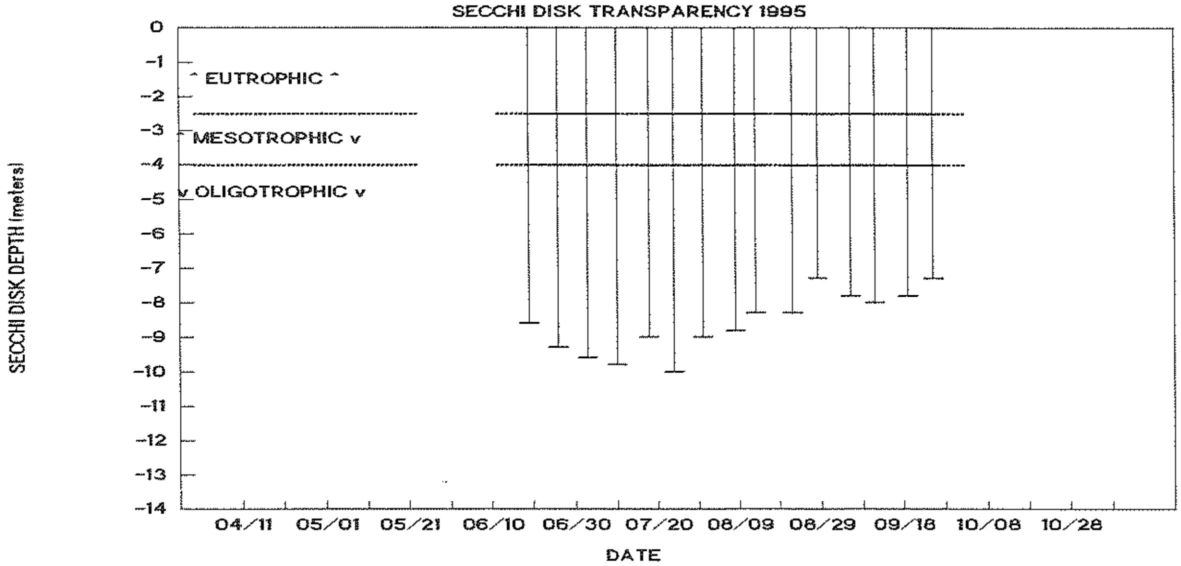
Figure 11. Long Island, 1995. Seasonal Secchi Disk (water transparency) trends for lay monitor Site 45 Ese Li. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 12. Long Island, 1995. Seasonal chlorophyll *a* trends for lay monitor Site 45 Ese Li. Chlorophyll *a* concentrations are expressed as parts per billion (ppb) chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 13. Long Island, 1995. Seasonal dissolved color trends for lay monitor Site 45 Ese Li. Dissolved color concentrations are expressed as platinum-cobalt units (ptu). The dotted horizontal line denotes the 1995 dissolved color concentration for **LLMP** lakes.

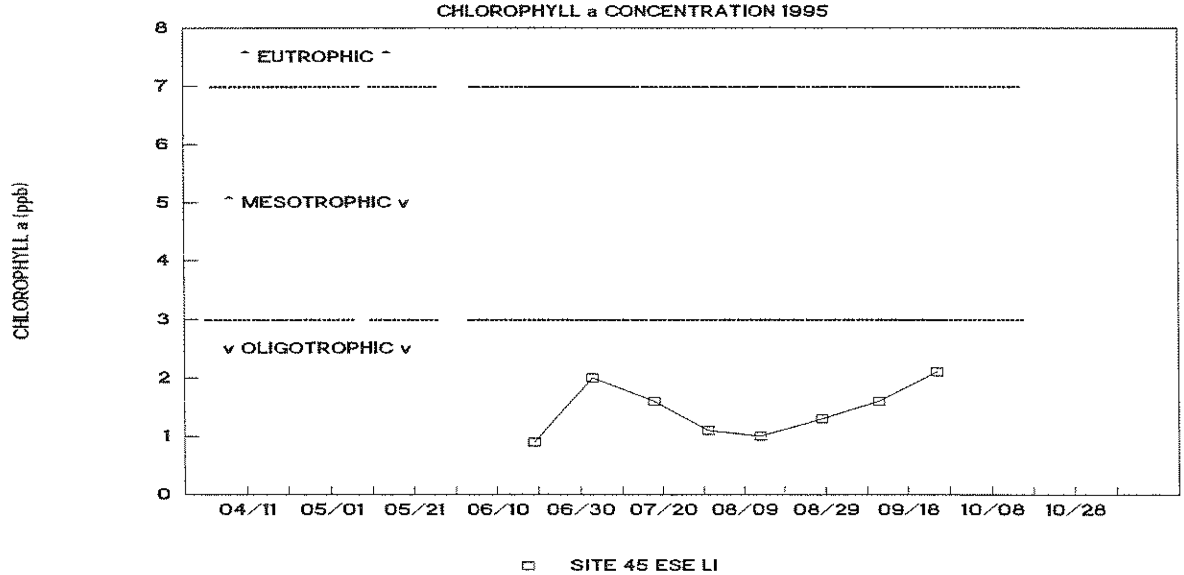
LONG ISLAND - SITE 45 ESE LI

SECCHI DISK TRANSPARENCY 1995



LONG ISLAND

CHLOROPHYLL a CONCENTRATION 1995



LONG ISLAND

DISSOLVED COLOR CONCENTRATION 1995

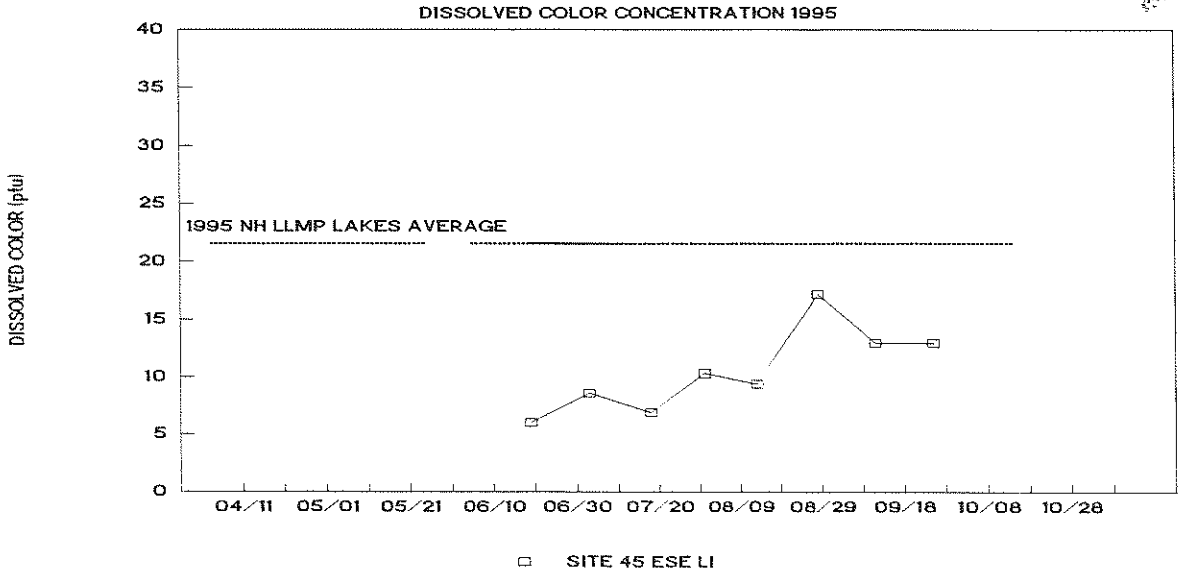
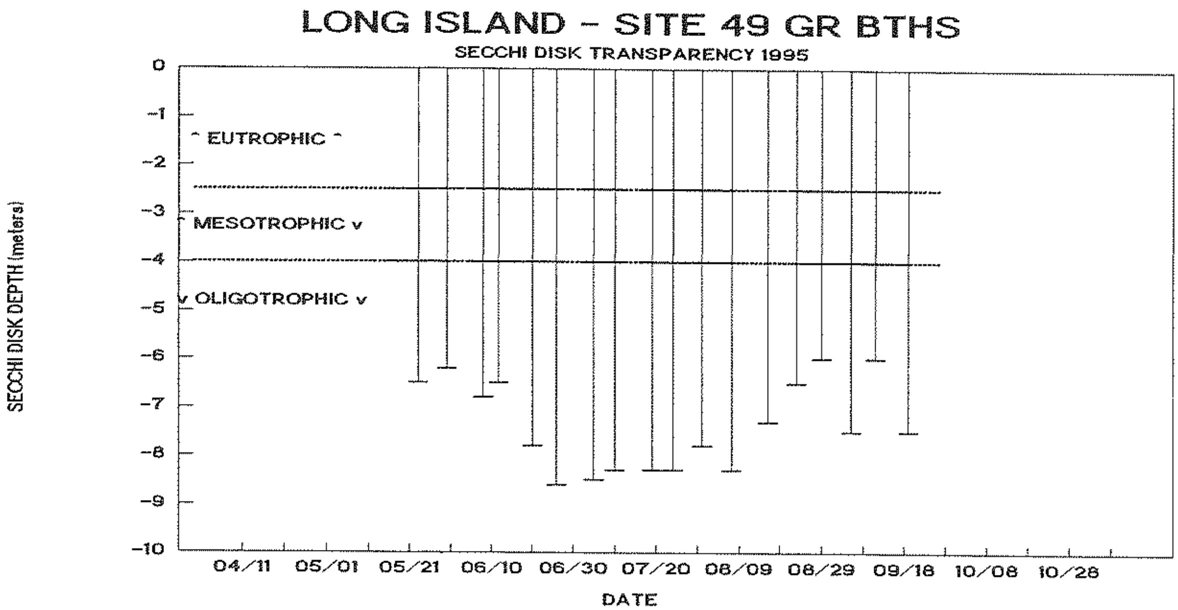
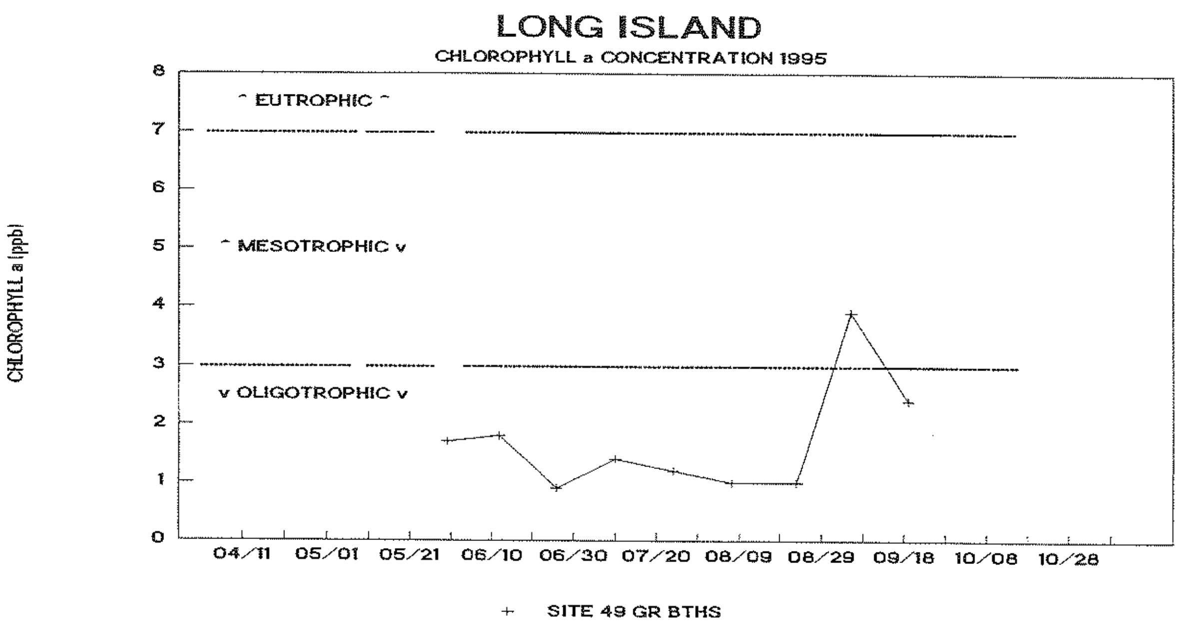


Figure 14. Long Island, 1995. Seasonal Secchi Disk (water transparency) trends for lay monitor Site 49 Green's Boathouse. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 15. Long Island, 1995. Seasonal chlorophyll *a* trends for lay monitor Site 49 Green's Boathouse. Chlorophyll *a* concentrations are expressed as parts per billion (ppb) chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 16. Long Island, 1995. Seasonal dissolved color trends for lay monitor Site 49 Green's Boathouse. Dissolved color concentrations are expressed as platinum-cobalt units (ptu). The dotted horizontal line denotes the 1995 dissolved color concentration for **LLMP** lakes.


LONG ISLAND - SITE 49 GR BTHS
SECCHI DISK TRANSPARENCY 1995
SECCHI DISK DEPTH (meters)
^ EUTROPHIC ^
^ MESOTROPHIC v
v OLIGOTROPHIC v
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
04/11
05/01
05/21
06/10
06/30
07/20
08/09
08/29
09/18
10/08
10/28
DATE


LONG ISLAND
CHLOROPHYLL a CONCENTRATION 1995
CHLOROPHYLL a (ppb)
^ EUTROPHIC ^
^ MESOTROPHIC v
v OLIGOTROPHIC v
8
7
6
5
4
3
2
1
0
04/11
05/01
05/21
06/10
06/30
07/20
08/09
08/29
09/18
10/08
10/28
+ SITE 49 GR BTHS

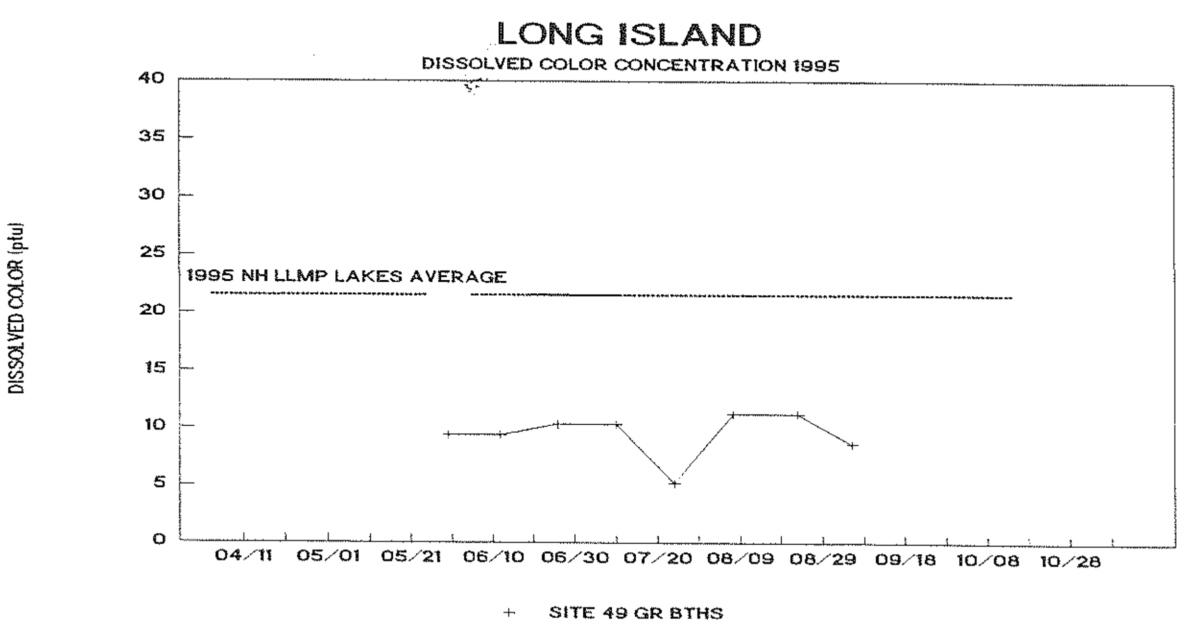
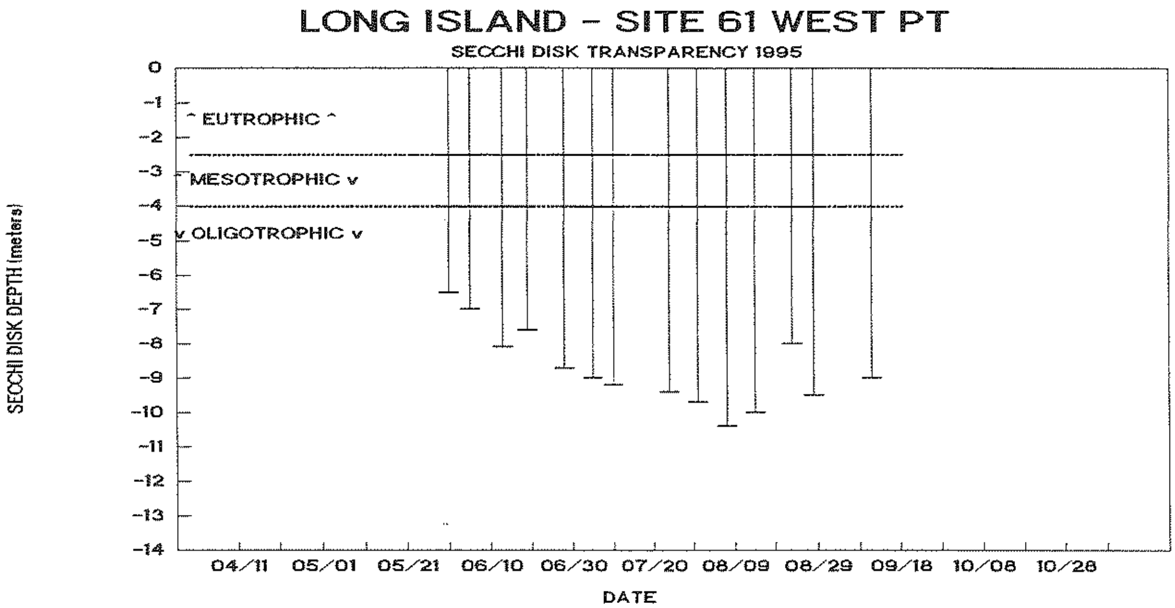

LONG ISLAND
DISSOLVED COLOR CONCENTRATION 1995
DISSOLVED COLOR (ptu)
1995 NH LLMP LAKES AVERAGE
40
35
30
25
20
15
10
5
0
04/11
05/01
05/21
06/10
06/30
07/20
08/09
08/29
09/18
10/08
10/28
+ SITE 49 GR BTHS

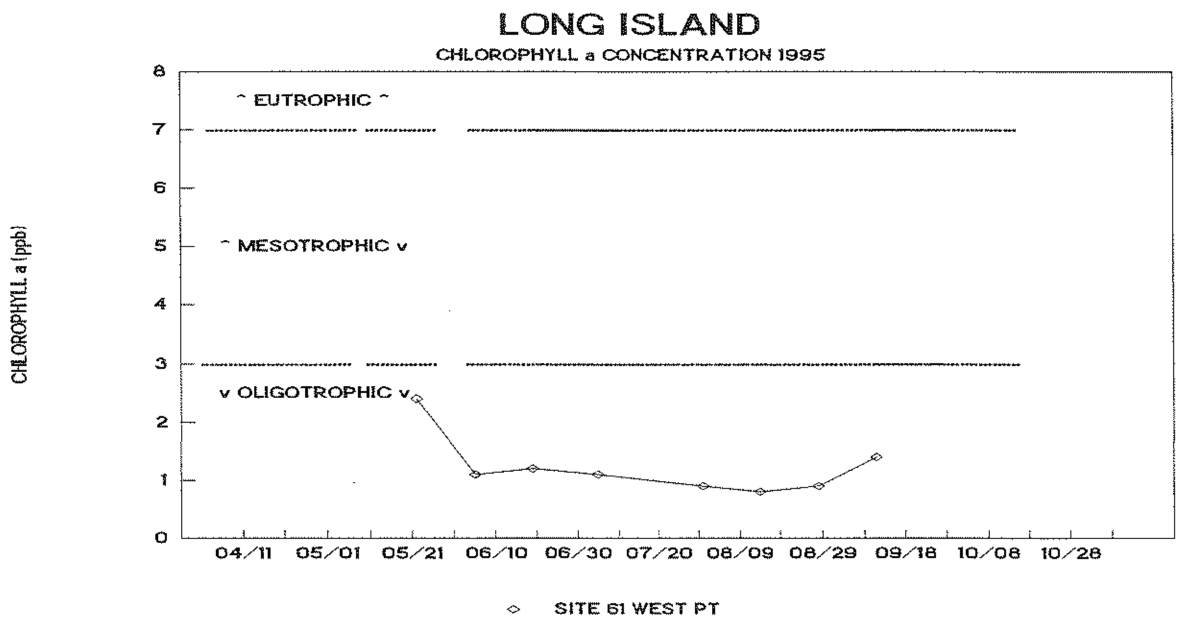
Figure 17. Long Island, 1995. Seasonal Secchi Disk (water transparency) trends for lay monitor Site 61 West Pt. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 18. Long Island, 1995. Seasonal chlorophyll *a* trends for lay monitor Site 61 West Pt. Chlorophyll *a* concentrations are expressed as parts per billion (ppb) chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

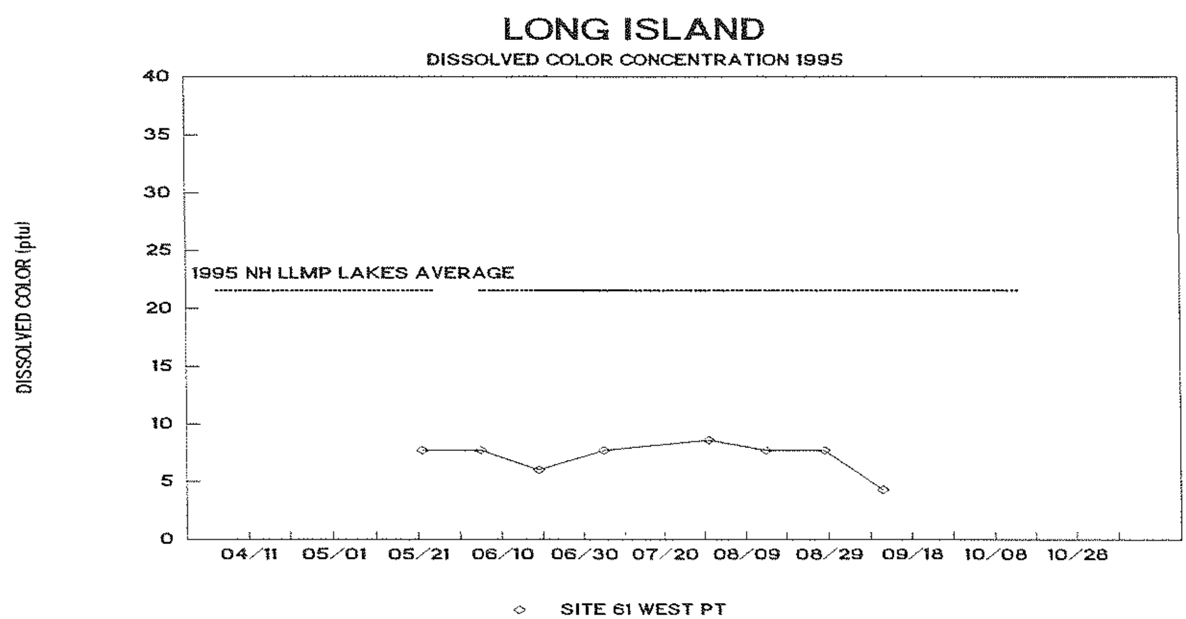
Figure 19. Long Island, 1995. Seasonal dissolved color trends for lay monitor Site 61 West Pt. Dissolved color concentrations are expressed as platinum-cobalt units (ptu). The dotted horizontal line denotes the 1995 dissolved color concentration for **LLMP** lakes.



LONG ISLAND - SITE 61 WEST PT
SECCHI DISK TRANSPARENCY 1995
SECCHI DISK DEPTH (meters)
^ EUTROPHIC ^
MESOTROPHIC v
v OLIGOTROPHIC v
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
04/11 05/01 05/21 06/10 06/30 07/20 08/09 08/29 09/18 10/08 10/28
DATE



LONG ISLAND
CHLOROPHYLL a CONCENTRATION 1995
CHLOROPHYLL a (ppb)
^ EUTROPHIC ^
^ MESOTROPHIC v
v OLIGOTROPHIC v
8
7
6
5
4
3
2
1
0
04/11 05/01 05/21 06/10 06/30 07/20 08/09 08/29 09/18 10/08 10/28
SITE 61 WEST PT



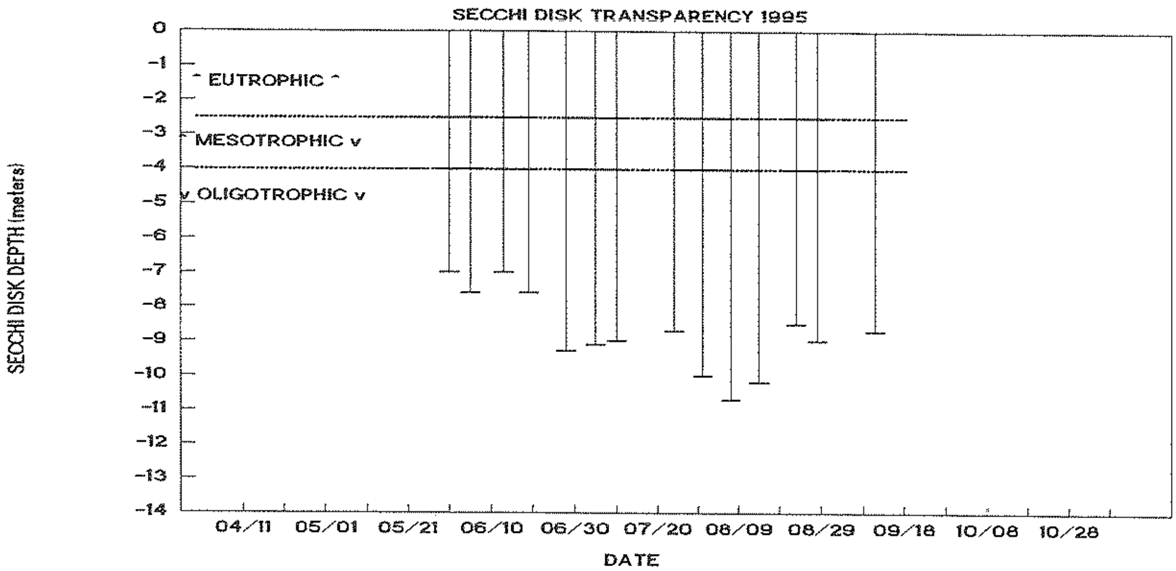
LONG ISLAND
DISSOLVED COLOR CONCENTRATION 1995
DISSOLVED COLOR (ptu)
1995 NH LLMP LAKES AVERAGE
40
35
30
25
20
15
10
5
0
04/11 05/01 05/21 06/10 06/30 07/20 08/09 08/29 09/18 10/08 10/28
SITE 61 WEST PT

Figure 20. Long Island, 1995. Seasonal Secchi Disk (water transparency) trends for lay monitor Site 64 Jonathan's Landing. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

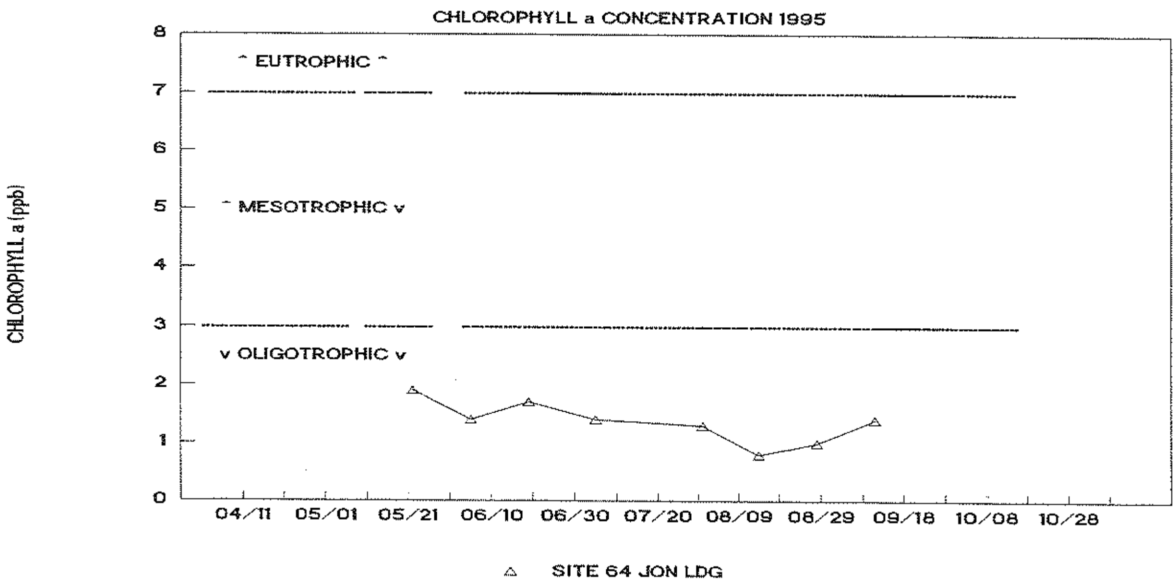
Figure 21. Long Island, 1995. Seasonal chlorophyll *a* trends for lay monitor Site 64 Jonathan's Landing. Chlorophyll *a* concentrations are expressed as parts per billion (ppb) chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 22. Long Island, 1995. Seasonal dissolved color trends for lay monitor Site 64 Jonathan's Landing. Dissolved color concentrations are expressed as platinum-cobalt units (ptu). The dotted horizontal line denotes the 1995 dissolved color concentration for **LLMP** lakes.

LONG ISLAND - SITE 64 JON LDG



LONG ISLAND



LONG ISLAND

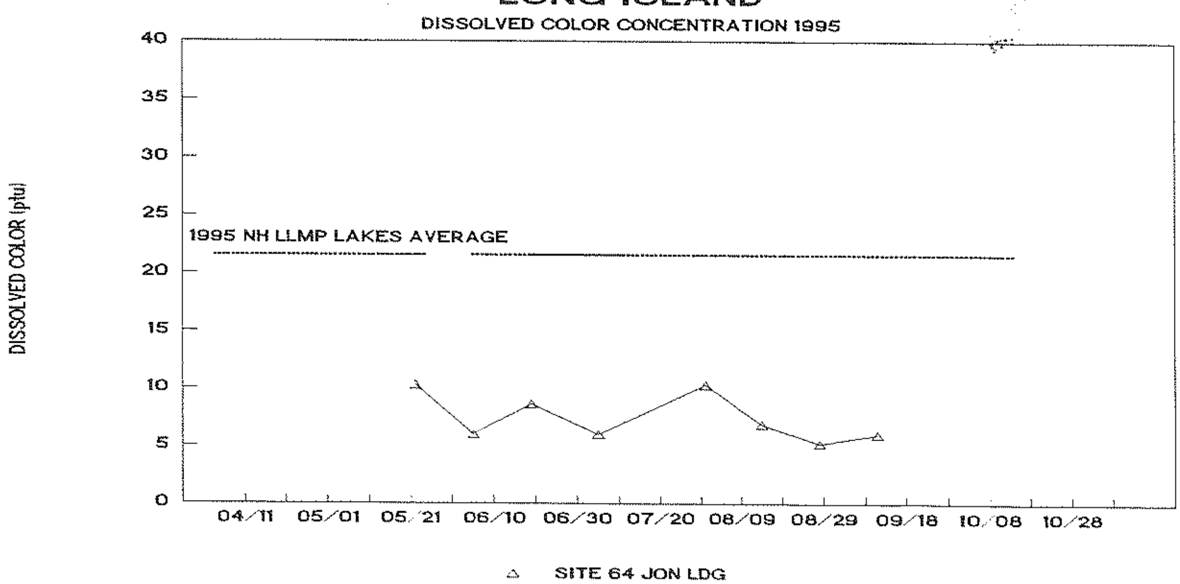
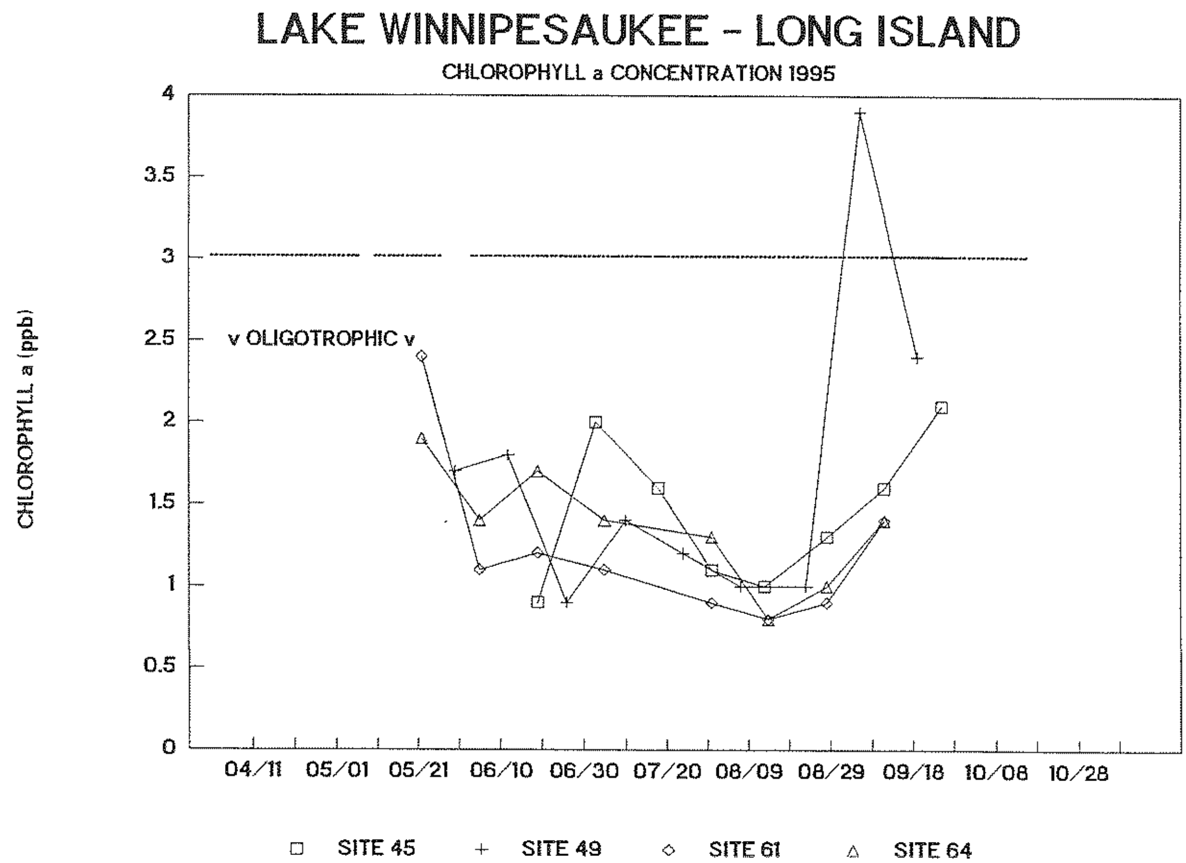
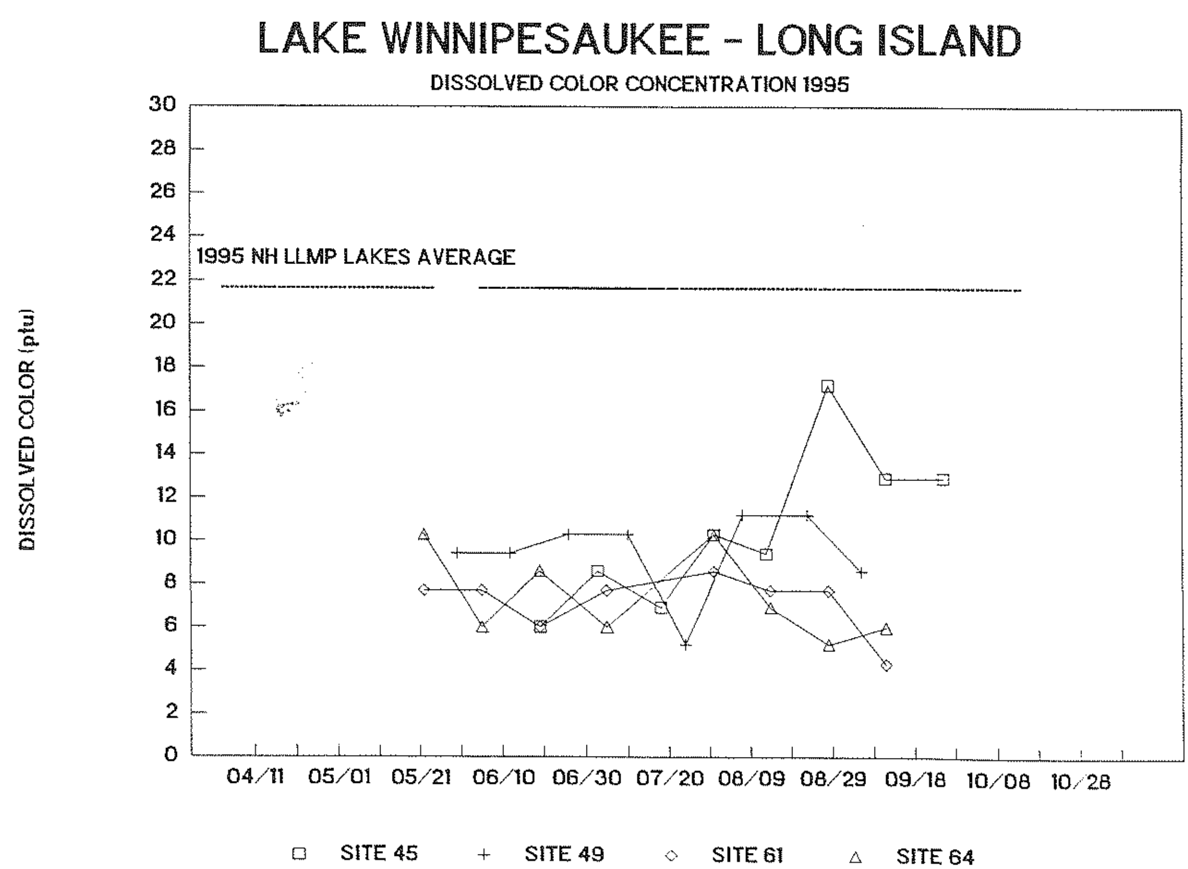


Figure 23. Long Island, 1995. Seasonal chlorophyll *a* trends for lay monitor Sites 45 (squares), 49 (crosses), 61 (diamonds) and 64 (triangles). Chlorophyll *a* concentrations are expressed as parts per billion (ppb) chlorophyll *a*. The dotted horizontal line on the plot borders the ranges common to oligotrophic and mesotrophic lakes.

Figure 24. Long Island, 1995. Seasonal dissolved color trends for lay monitor Sites 45 (squares), 49 (crosses), 61 (diamonds) and 64 (triangles). Dissolved color concentrations are expressed as platinum-cobalt units (ptu). The dotted horizontal line denotes the 1995 dissolved color concentration for **LLMP** lakes.



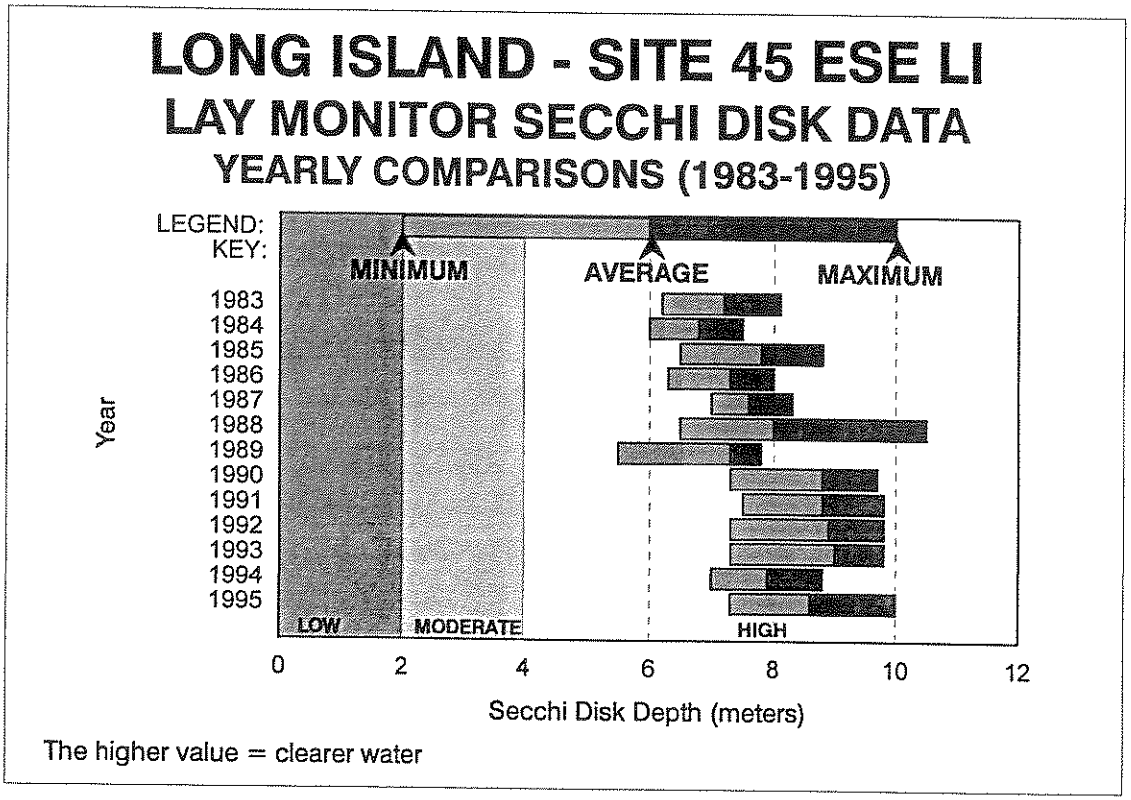
LAKE WINNIPESAUKEE - LONG ISLAND
CHLOROPHYLL a CONCENTRATION 1995
CHLOROPHYLL a (ppb)
4
3.5
3
2.5
2
1.5
1
0.5
0
v OLIGOTROPHIC v
04/11
05/01
05/21
06/10
06/30
07/20
08/09
08/29
09/18
10/08
10/28
SITE 45
SITE 49
SITE 61
SITE 64



LAKE WINNIPESAUKEE - LONG ISLAND
DISSOLVED COLOR CONCENTRATION 1995
DISSOLVED COLOR (ptu)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1995 NH LLMP LAKES AVERAGE
04/11
05/01
05/21
06/10
06/30
07/20
08/09
08/29
09/18
10/08
10/28
SITE 45
SITE 49
SITE 61
SITE 64

Figure 25. Comparison of the 1995 Long Island, Site 45 Ese Li, lay monitor Secchi Disk transparency data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the ranges characteristic of low, moderate and high Secchi Disk transparencies. The higher the Secchi Disk value the clearer the water. Secchi Disk readings are measured to the nearest tenth (0.1) of a meter.

Figure 26. Comparison of the 1995 Long Island, Site 45 Ese Li., lay monitor chlorophyll *a* data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote chlorophyll *a* concentrations typical of unproductive and moderately productive lakes. The higher the chlorophyll *a* concentration the greener the water (i.e. more algal growth).


LONG ISLAND - SITE 45 ESE LI
LAY MONITOR SECCHI DISK DATA
YEARLY COMPARISONS (1983-1995)
LEGEND:
KEY:
MINIMUM
AVERAGE
MAXIMUM
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
Year
LOW
MODERATE
HIGH
0
2
4
6
8
10
12
Secchi Disk Depth (meters)
The higher value = clearer water

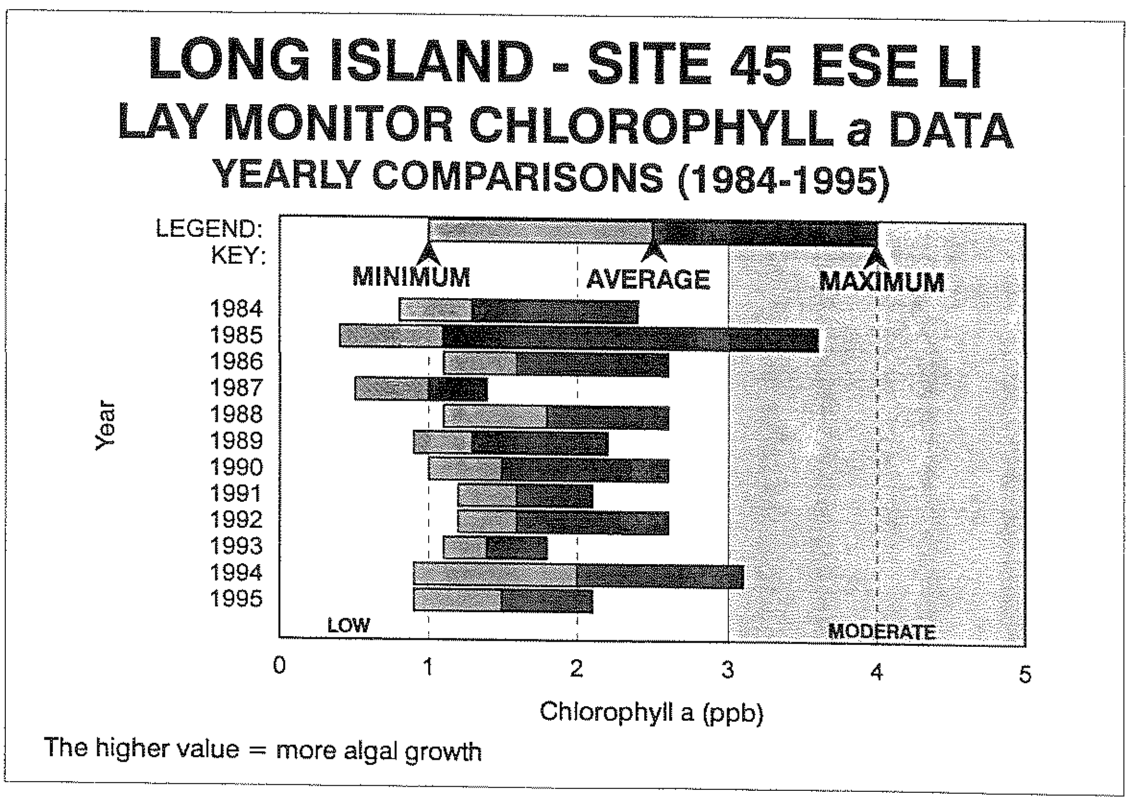
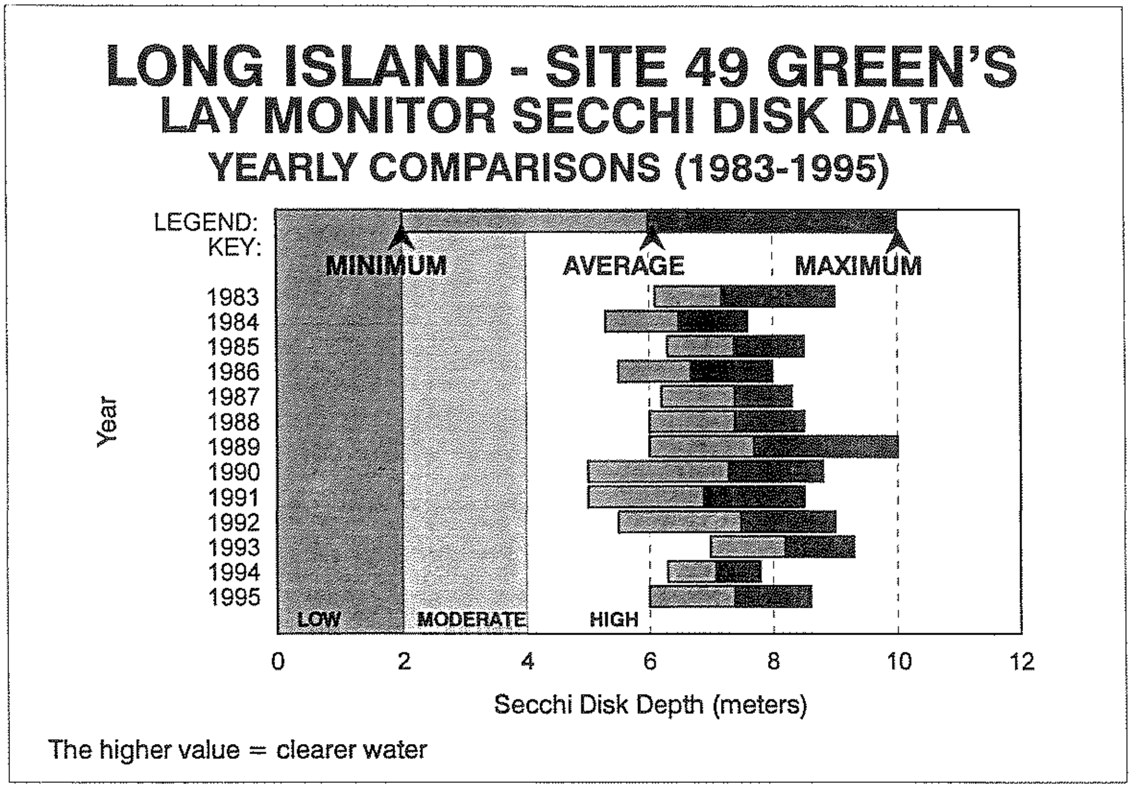
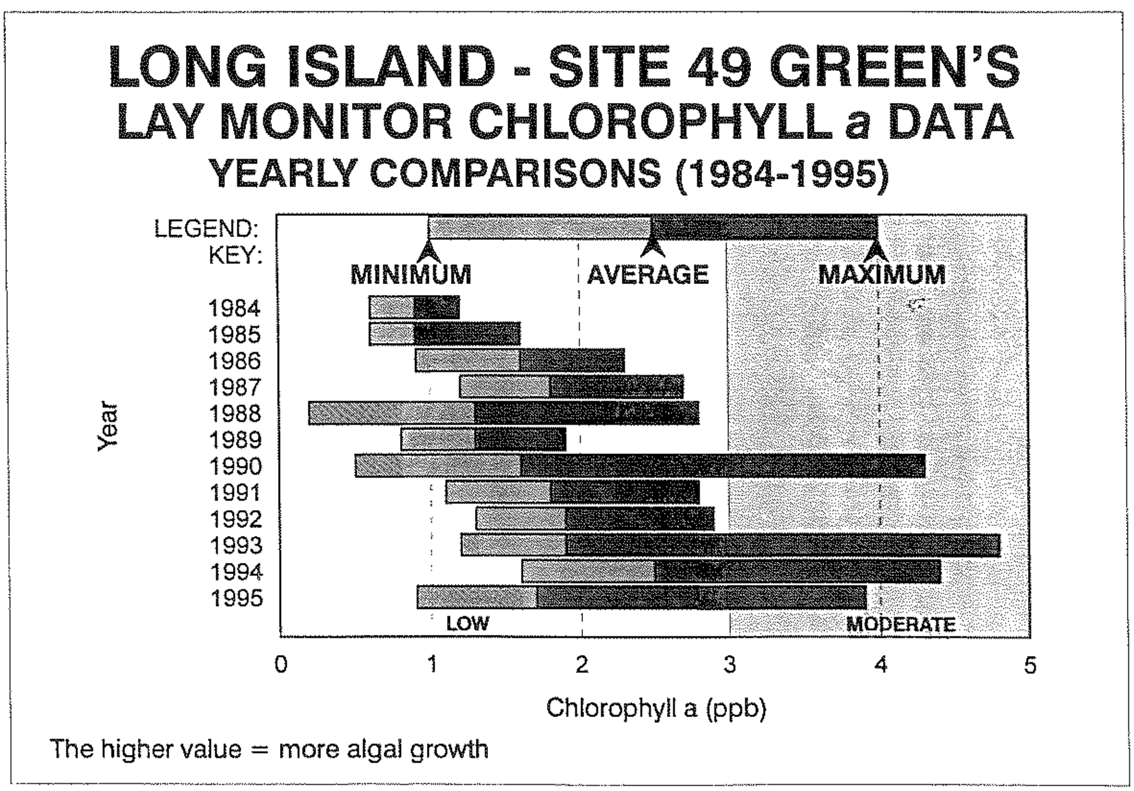

LONG ISLAND - SITE 45 ESE LI
LAY MONITOR CHLOROPHYLL a DATA
YEARLY COMPARISONS (1984-1995)
LEGEND:
KEY:
MINIMUM
AVERAGE
MAXIMUM
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
Year
LOW
MODERATE
0
1
2
3
4
5
Chlorophyll a (ppb)
The higher value = more algal growth

Figure 27. Comparison of the 1995 Long Island, Site 49 Green's Boathouse, lay monitor Secchi Disk transparency data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the ranges characteristic of low, moderate and high Secchi Disk transparencies. The higher the Secchi Disk value the clearer the water. Secchi Disk readings are measured to the nearest tenth (0.1) of a meter.

Figure 28. Comparison of the 1995 Long Island, Site 49 Green's Boathouse, lay monitor chlorophyll *a* data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote chlorophyll *a* concentrations typical of unproductive and moderately productive lakes. The higher the chlorophyll *a* concentration the greener the water (i.e. more algal growth).



LONG ISLAND - SITE 49 GREEN'S
LAY MONITOR SECCHI DISK DATA
YEARLY COMPARISONS (1983-1995)
LEGEND:
KEY:
MINIMUM
AVERAGE
MAXIMUM
Year
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
LOW
MODERATE
HIGH
0
2
4
6
8
10
12
Secchi Disk Depth (meters)
The higher value = clearer water

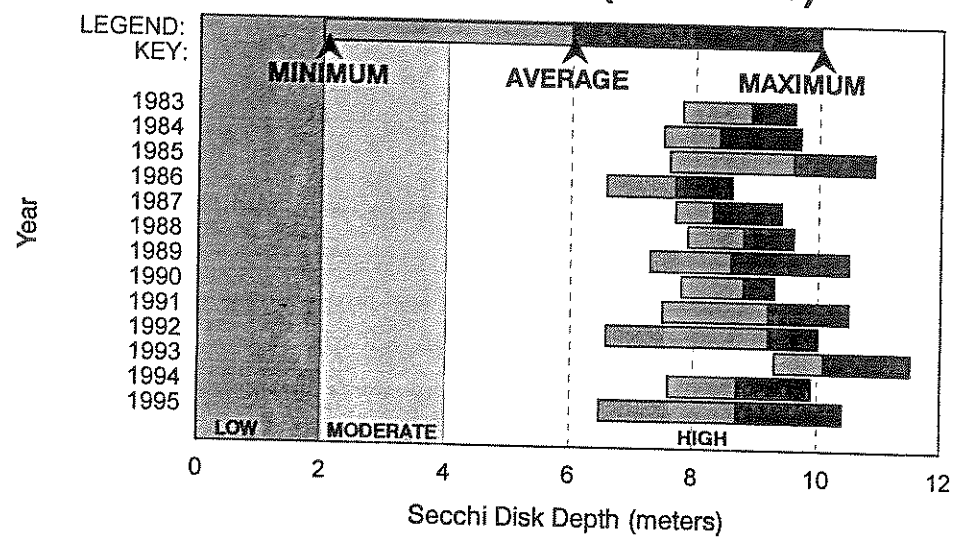


LONG ISLAND - SITE 49 GREEN'S
LAY MONITOR CHLOROPHYLL a DATA
YEARLY COMPARISONS (1984-1995)
LEGEND:
KEY:
MINIMUM
AVERAGE
MAXIMUM
Year
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
LOW
MODERATE
0
1
2
3
4
5
Chlorophyll a (ppb)
The higher value = more algal growth

Figure 29. Comparison of the 1995 Long Island, Site 61 West Point, lay monitor Secchi Disk transparency data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the ranges characteristic of low, moderate and high Secchi Disk transparencies. The higher the Secchi Disk value the clearer the water. Secchi Disk readings are measured to the nearest tenth (0.1) of a meter.

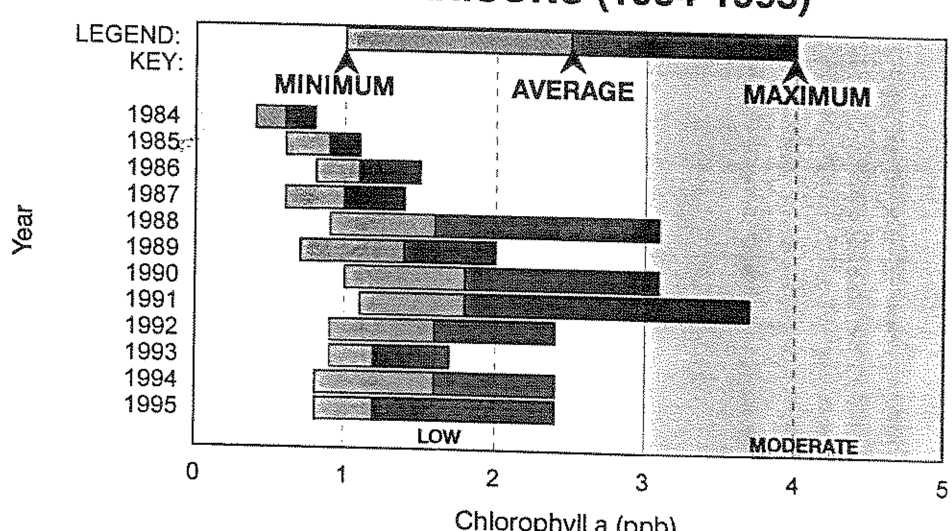
Figure 30. Comparison of the 1995 Long Island, Site 61 West Point, lay monitor chlorophyll *a* data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote chlorophyll *a* concentrations typical of unproductive and moderately productive lakes. The higher the chlorophyll *a* concentration the greener the water (i.e. more algal growth).

LONG ISLAND - SITE 61 WEST POINT
LAY MONITOR SECCHI DISK DATA
YEARLY COMPARISONS (1983-1995)



The higher value = clearer water

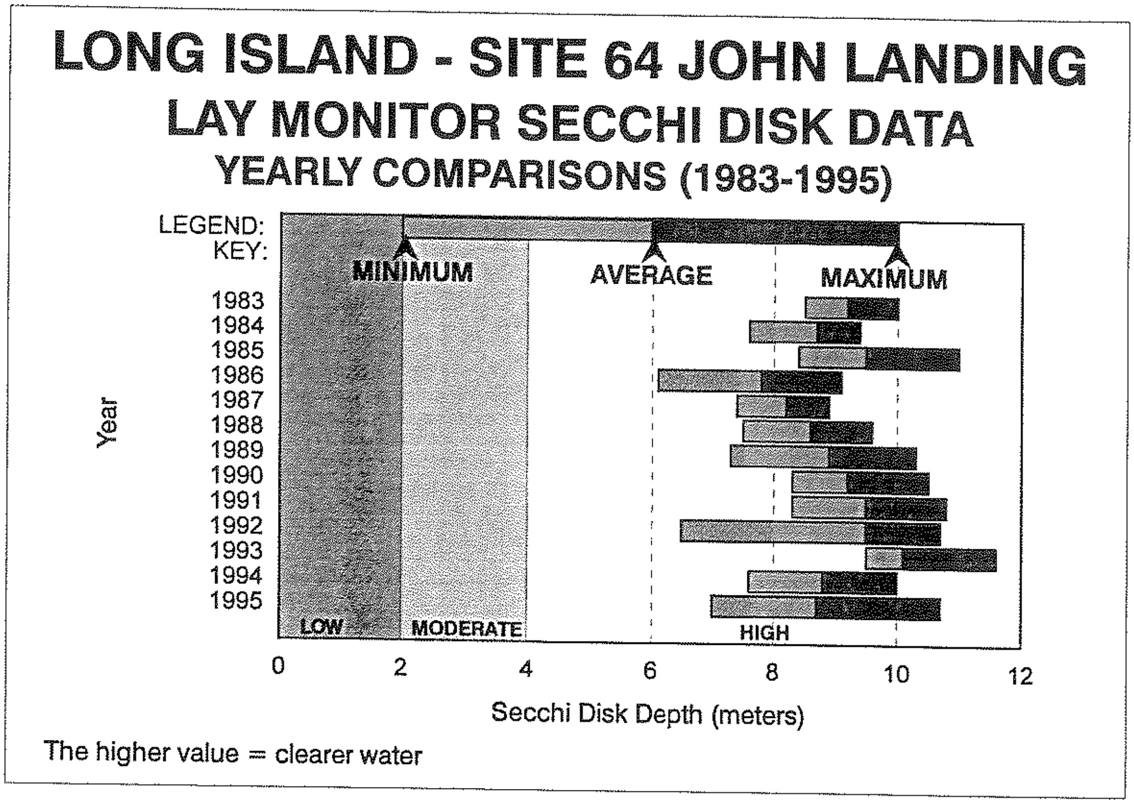
LONG ISLAND - SITE 61 WEST POINT
LAY MONITOR CHLOROPHYLL *a* DATA
YEARLY COMPARISONS (1984-1995)



The higher value = more algal growth

Figure 31. Comparison of the 1995 Long Island, Site 64 Jonathan's Landing, lay monitor Secchi Disk transparency data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the ranges characteristic of low, moderate and high Secchi Disk transparencies. The higher the Secchi Disk value the clearer the water. Secchi Disk readings are measured to the nearest tenth (0.1) of a meter.

Figure 32. Comparison of the 1995 Long Island, Site 64 Jonathan's Landing, lay monitor chlorophyll *a* data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote chlorophyll *a* concentrations typical of unproductive and moderately productive lakes. The higher the chlorophyll *a* concentration the greener the water (i.e. more algal growth).


LONG ISLAND - SITE 64 JOHN LANDING
LAY MONITOR SECCHI DISK DATA
YEARLY COMPARISONS (1983-1995)
LEGEND:
KEY:
MINIMUM
AVERAGE
MAXIMUM
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
Year
LOW
MODERATE
HIGH
0
2
4
6
8
10
12
Secchi Disk Depth (meters)
The higher value = clearer water

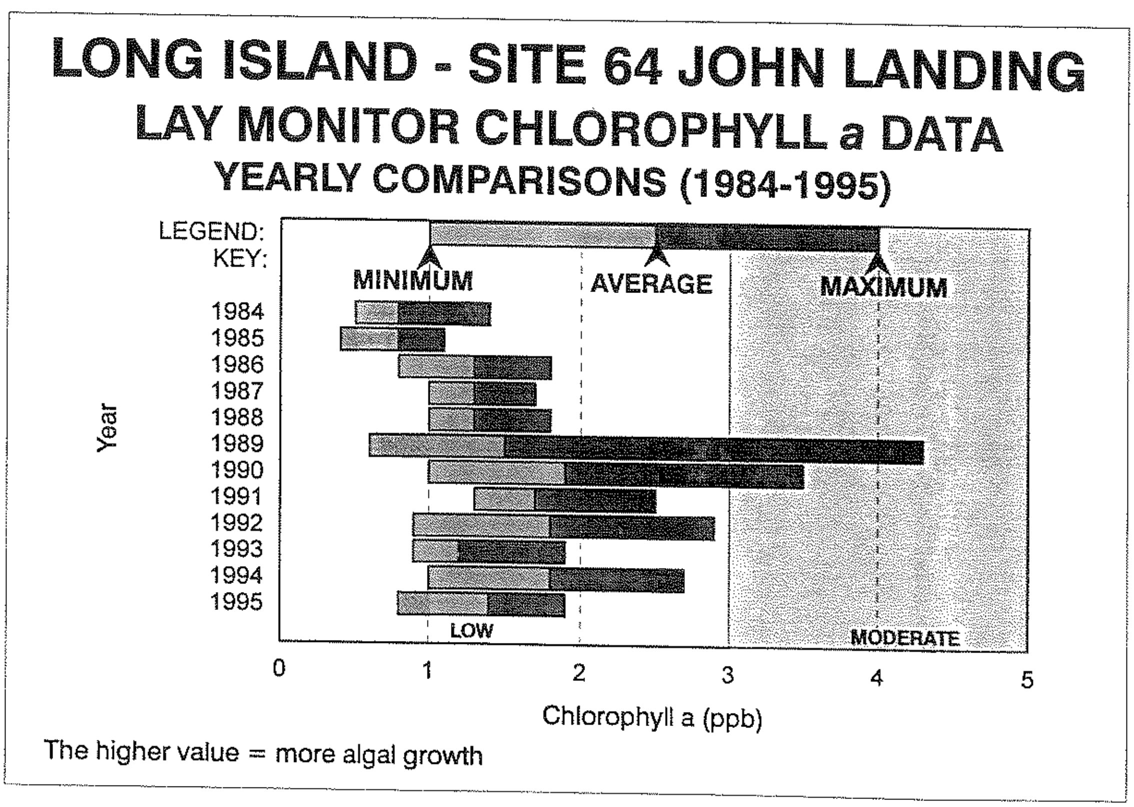
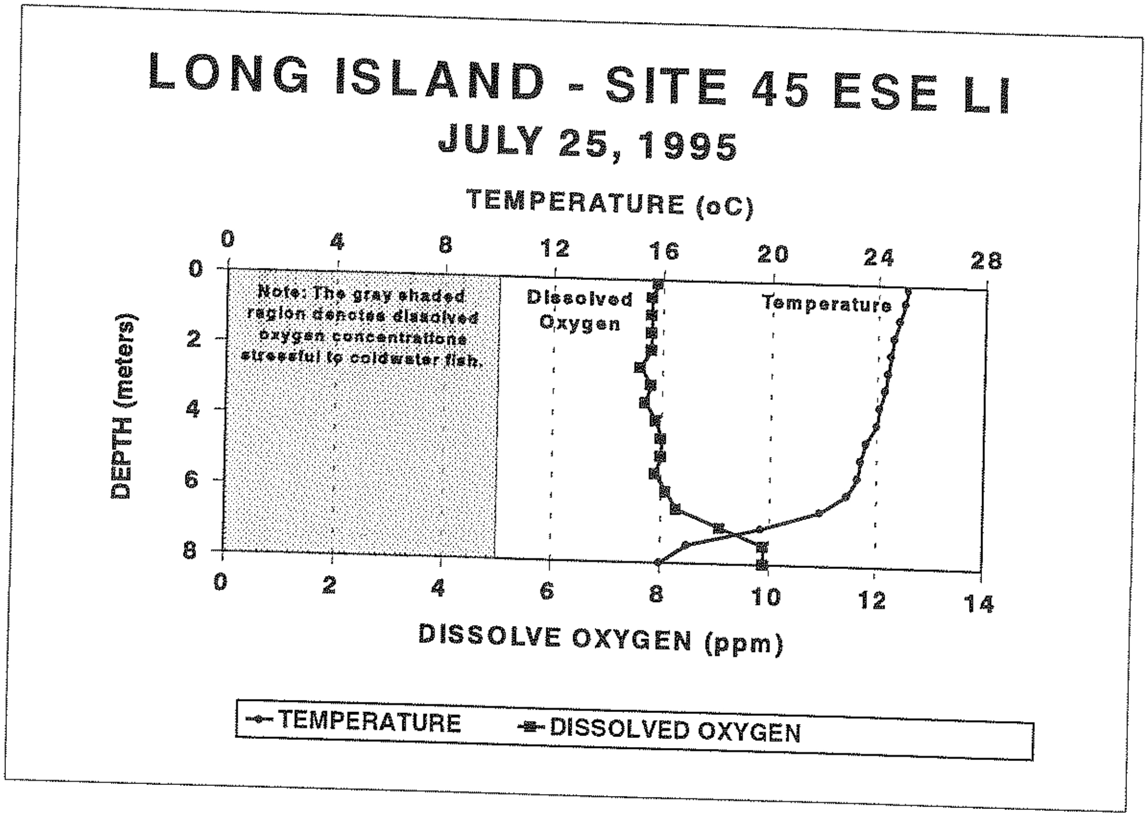
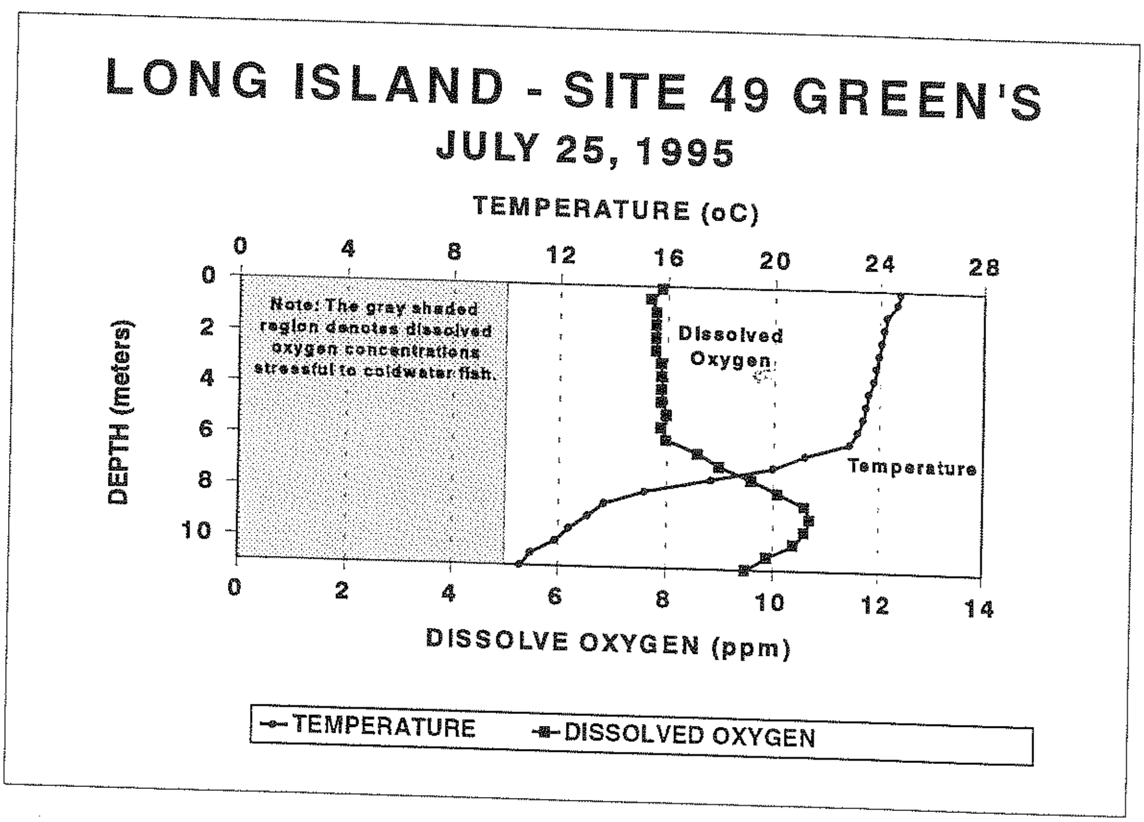

LONG ISLAND - SITE 64 JOHN LANDING
LAY MONITOR CHLOROPHYLL a DATA
YEARLY COMPARISONS (1984-1995)
LEGEND:
KEY:
MINIMUM
AVERAGE
MAXIMUM
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
Year
LOW
MODERATE
0
1
2
3
4
5
Chlorophyll a (ppb)
The higher value = more algal growth

Figure 33. Temperature and dissolved oxygen profiles depicting data collected on July 25, 1995 at the 45 Ese Li and 49 Green's Boathouse sampling locations. The temperature and dissolved oxygen data were collected at one-half meter increments and are in degrees Celsius and in parts per million, respectively. The gray shaded region on the graph denotes dissolved oxygen concentrations stressful to coldwater fish species.



LONG ISLAND - SITE 45 ESE LI
JULY 25, 1995
TEMPERATURE (oC)
0 4 8 12 16 20 24 28
DEPTH (meters)
0 2 4 6 8
Note: The gray shaded region denotes dissolved oxygen concentrations stressful to coldwater fish.
Dissolved Oxygen
Temperature
0 2 4 6 8 10 12 14
DISSOLVE OXYGEN (ppm)
TEMPERATURE
DISSOLVED OXYGEN



LONG ISLAND - SITE 49 GREEN'S
JULY 25, 1995
TEMPERATURE (oC)
0 4 8 12 16 20 24 28
DEPTH (meters)
0 2 4 6 8 10
Note: The gray shaded region denotes dissolved oxygen concentrations stressful to coldwater fish.
Dissolved Oxygen
Temperature
0 2 4 6 8 10 12 14
DISSOLVE OXYGEN (ppm)
TEMPERATURE
DISSOLVED OXYGEN

Figure 34. Temperature and dissolved oxygen profiles depicting data collected on July 25, 1995 at Site 64 Jonathan's Landing. The temperature and dissolved oxygen data were collected at one-half meter increments and are in degrees Celsius and in parts per million, respectively. The gray shaded region on the graph denotes dissolved oxygen concentrations stressful to cold-water fish species.

LONG ISLAND - SITE 64 JON LDG

JULY 25, 1995

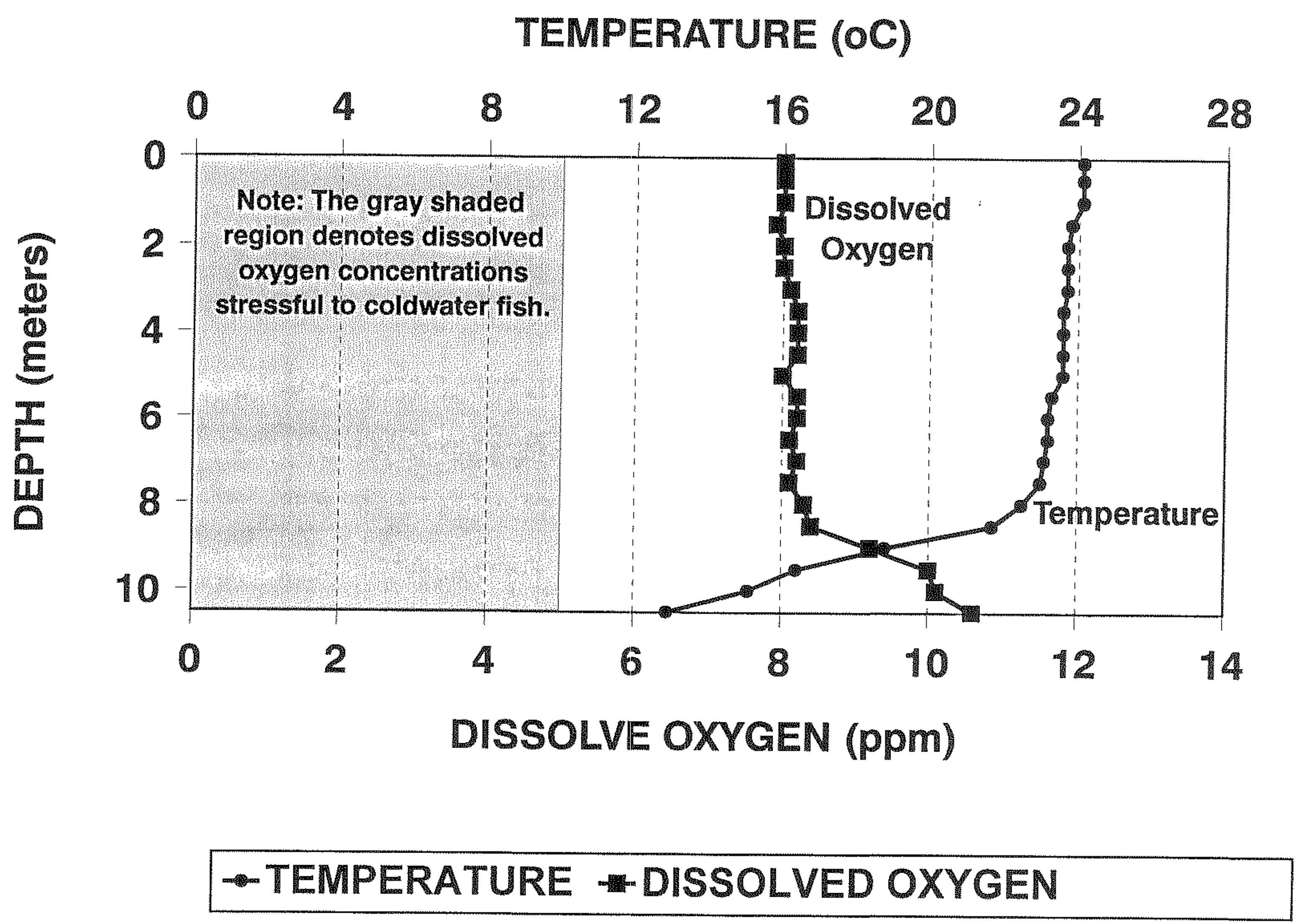
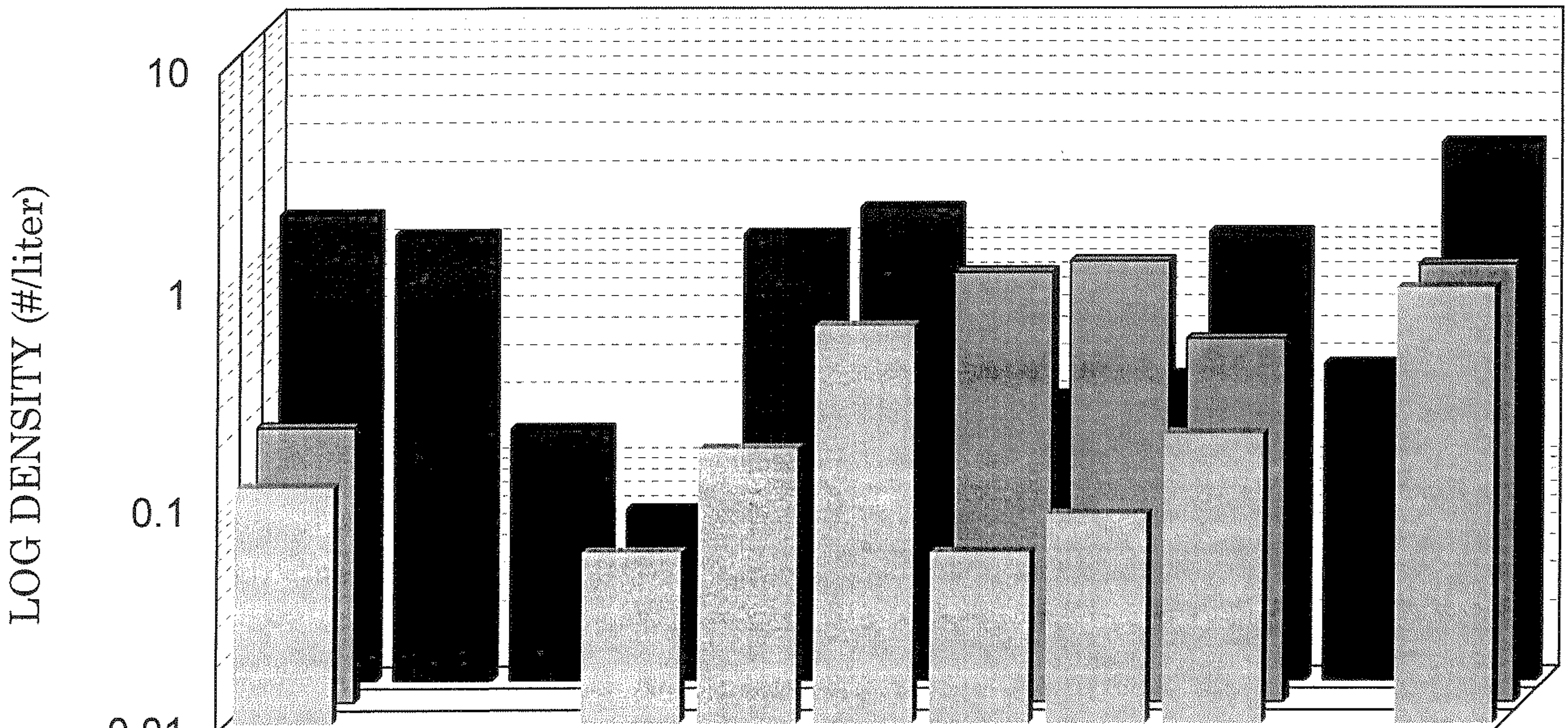


Figure 35. Long Island, Sites 45 Ese Li., 49 Green's Boathouse and 64 Jonathan's Landing, macro-zooplankton data depicting the Cladoceran community composition on July 25, 1995. Macro-zooplankton data were collected by pulling a 64 micron mesh net vertically through the water column and retaining the net contents for microscopic analysis. The macro-zooplankton densities are presented as number of animals per liter.

LONG ISLAND (JULY 25, 1995)

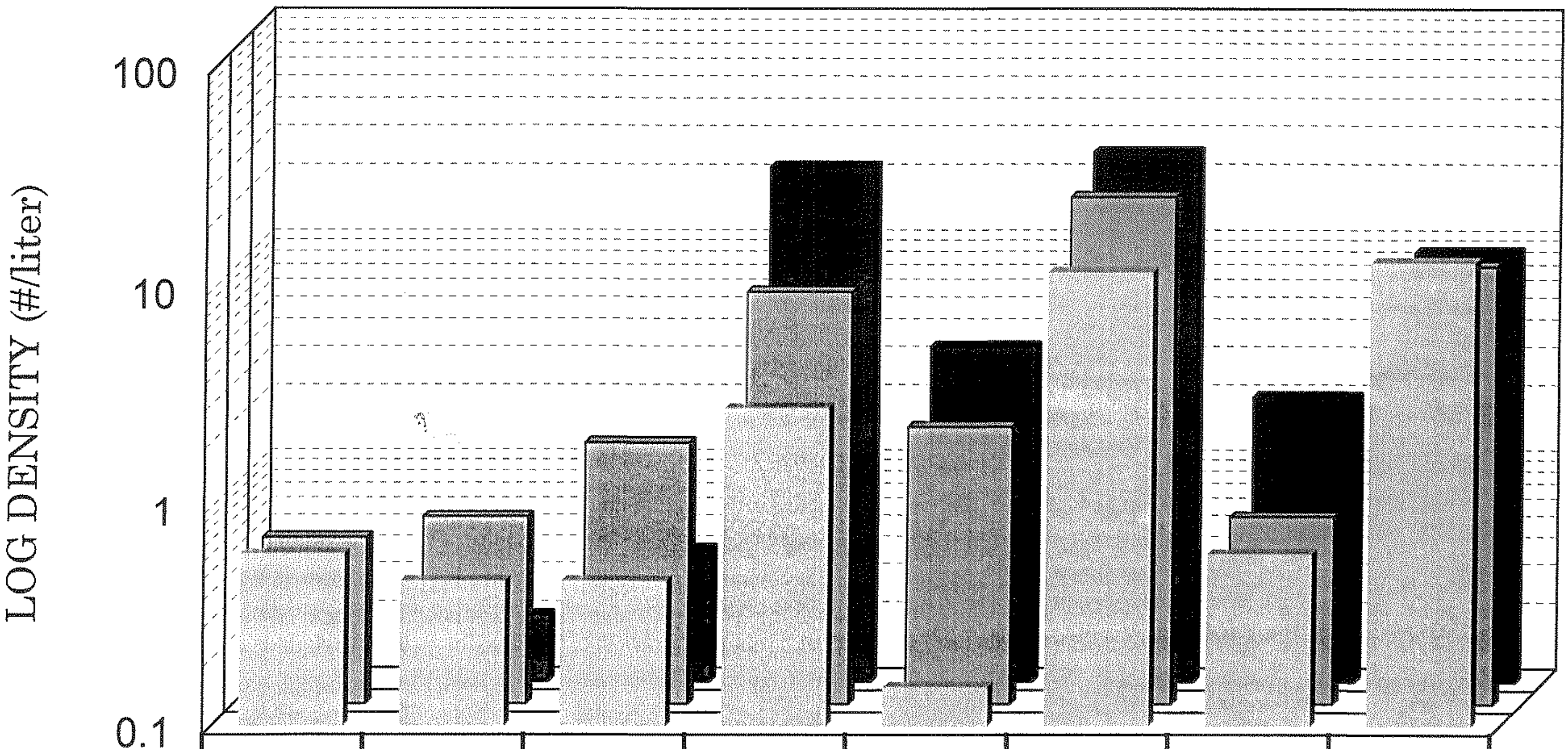
MACROZOOPLANKTON SPECIES COMPOSITION (CLADOCERANS AND COPEPODS)



	Daphnia spp.	Bosmina lon	Ceriodaph spp	Diaphan spp.	Eubosmina	Holopedium	Cyclopoids	Cyc. copepodid	Diaptomus	Epischura	Cal. copepodid
45 Ese Li	0.12	0	0	0.06	0.18	0.66	0.06	0.09	0.21	0	0.98
64 Jon Ldg	0.18		0		0	0	0.92	1.03	0.46	0	0.99
49 Green's	1.33	1.08	0.14	0.06	1.08	1.42	0.2	0.25	1.1	0.28	2.77

Figure 36. Long Island, Sites 45 Ese Li., 49 Green's Boathouse and 64 Jonathan's Landing, micro-zooplankton data depicting the Rotifer and Nauplii community composition on July 25, 1995. Micro-zooplankton data were collected by pulling a 64 micron mesh net vertically through the water column and retaining the net contents for microscopic analysis. The micro-zooplankton densities are presented as number of animals per liter.

LONG ISLAND (JULY 25, 1995)
MICROZOOPLANKTON SPECIES COMPOSITION (NAUPLII AND ROTIFERS)



	Asplanchna spp.	*Conochilus spp.*	*Kellicotia long.*	*Ker "cochlearis"*	*Ker tauroceph*	*Polyarthra spp.*	*Tricocerca spp.*	*Nauplii*
64 Jon Ldg	0.6	0.45	0.45	2.83	0.15	11.77	0.6	12.96
49 Green's	0.57	0.71	1.56	7.64	1.84	20.38	0.71	9.91
45 Ese Li	0	0.2	0.4	22.44	3.44	26.08	2.02	9.1

APPENDIX A

Lakes Lay Monitoring Program, U.N.H.
[Lay Monitor Data]

Lake Winnipisaukee - Long Island, NH
-- subset of trophic indicators, all sites, 1995

1995 SUMMARY

Average transparency:	8.3	(1995: 61 values;	6.0	- 10.7	range)
Average chlorophyll:	1.4	(1995: 33 values;	0.8	- 3.9	range)
Average phosphorus:	18.2	(1995: 11 values;	3.5	- 103.2	range)
Average alk (gray):	6.5	(1995: 30 values;	6.0	- 6.8	range)
Average alk (pink):	7.2	(1995: 30 values;	6.4	- 8.0	range)
Average color, 440:	8.6	(1995: 32 values;	4.3	- 17.2	range)

Site	Date	Trans-parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
45 Ese Li	06/19/1995	8.6	0.9	----	6.5	7.4	6.0
45 Ese Li	06/26/1995	9.3	----	----	6.8	8.0	----
45 Ese Li	07/03/1995	9.6	2.0	----	6.5	7.3	8.6
45 Ese Li	07/10/1995	9.8	----	----	6.5	7.6	----
45 Ese Li	07/18/1995	9.0	1.6	5.1	6.6	7.7	6.9
45 Ese Li	07/24/1995	10.0	----	----	6.3	7.5	----
45 Ese Li	07/31/1995	9.0	1.1	----	6.7	7.7	10.3
45 Ese Li	08/08/1995	8.8	----	----	6.6	7.5	----
45 Ese Li	08/13/1995	8.3	1.0	----	6.6	7.6	9.4
45 Ese Li	08/22/1995	8.3	----	----	6.6	7.6	----
45 Ese Li	08/28/1995	7.3	1.3	----	6.7	7.4	17.2
45 Ese Li	09/05/1995	7.8	----	----	6.4	7.4	----
45 Ese Li	09/11/1995	8.0	1.6	----	6.7	7.6	12.9
45 Ese Li	09/19/1995	7.8	----	----	6.6	7.5	----
45 Ese Li	09/25/1995	7.3	2.1	6.8	6.6	7.4	12.9
49 Green's	05/23/1995	6.5	----	----	----	----	----
49 Green's	05/30/1995	6.2	1.7	19.8	----	----	9.4
49 Green's	06/08/1995	6.8	----	----	----	----	----
49 Green's	06/12/1995	6.5	1.8	----	----	----	9.4
49 Green's	06/20/1995	7.8	----	----	----	----	----
49 Green's	06/26/1995	8.6	0.9	----	----	----	10.3
49 Green's	07/05/1995	8.5	----	----	----	----	----
49 Green's	07/10/1995	8.3	1.4	----	----	----	10.3
49 Green's	07/19/1995	8.3	----	----	----	----	----

Site	Date	Trans-parency (m)	Chl *a* (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
49 Green's	07/24/1995	8.3	1.2	8.9	----	----	5.2
49 Green's	07/31/1995	7.8	----	----	----	----	----
49 Green's	08/07/1995	8.3	1.0	----	----	----	11.2
49 Green's	08/16/1995	7.3	----	----	----	----	----
49 Green's	08/23/1995	6.5	1.0	----	----	----	11.2
49 Green's	08/29/1995	6.0	----	----	----	----	----
49 Green's	09/05/1995	7.5	3.9	----	----	----	8.6
49 Green's	09/11/1995	6.0	----	----	----	----	-1.
49 Green's	09/19/1995	7.5	2.4	16.5	----	----	----
61 West Pt	05/22/1995	----	2.4	----	----	----	7.7
61 West Pt	05/31/1995	6.5	----	----	----	----	----
61 West Pt	06/05/1995	7.0	1.1	----	----	----	7.7
61 West Pt	06/13/1995	8.1	----	----	----	----	----
61 West Pt	06/19/1995	7.6	1.2	----	----	----	6.0
61 West Pt	06/28/1995	8.7	----	----	----	----	----
61 West Pt	07/05/1995	9.0	1.1	----	----	----	7.7
61 West Pt	07/10/1995	9.2	----	----	----	----	----
61 West Pt	07/24/1995	9.4	----	4.1	----	----	----
61 West Pt	07/31/1995	9.7	0.9	----	----	----	8.6
61 West Pt	08/07/1995	10.4	----	----	----	----	----
61 West Pt	08/14/1995	10.0	0.8	----	----	----	7.7
61 West Pt	08/23/1995	8.0	----	----	----	----	----
61 West Pt	08/28/1995	9.5	0.9	----	----	----	7.7
61 West Pt	09/11/1995	9.0	1.4	103.2	----	----	4.3
64 Jon Ldg	05/22/1995	----	1.9	15.5	6.0	6.4	10.3
64 Jon Ldg	05/31/1995	7.0	----	----	6.2	6.7	----
64 Jon Ldg	06/05/1995	7.6	1.4	----	6.5	7.1	6.0
64 Jon Ldg	06/13/1995	7.0	----	----	6.3	6.8	----
64 Jon Ldg	06/19/1995	7.6	1.7	----	6.3	6.6	8.6
64 Jon Ldg	06/28/1995	9.3	----	----	6.6	7.2	----
64 Jon Ldg	07/05/1995	9.1	1.4	----	6.0	6.5	6.0
64 Jon Ldg	07/10/1995	9.0	----	----	6.5	7.1	----
64 Jon Ldg	07/24/1995	8.7	----	3.5	6.3	6.7	----
64 Jon Ldg	07/31/1995	10.0	1.3	----	6.3	6.9	10.3
64 Jon Ldg	08/07/1995	10.7	----	----	6.2	6.7	----
64 Jon Ldg	08/14/1995	10.2	0.8	----	6.5	7.0	6.9
64 Jon Ldg	08/23/1995	8.5	----	----	6.5	6.9	----
64 Jon Ldg	08/28/1995	9.0	1.0	----	6.4	6.8	5.2
64 Jon Ldg	09/11/1995	8.7	1.4	9.1	6.3	6.9	6.0
LeeShr	07/21/1995	----	----	7.9	----	----	----

<< End of 1995 listing, 64 records >>

Historical Secchi Disk Transparency Data (1983-1995)
[Lay Monitor Data]

Site	Year	Minimum Secchi Disk Transparenc (meters)	Average Secchi Disk Transparenc (meters)	Maximum Secchi Disk Transparenc (meters)	Sample Size
45 Ese Li	1983	6.2	7.2	8.1	11
45 Ese Li	1984	6.0	6.8	7.5	18
45 Ese Li	1985	6.5	7.8	8.8	17
45 Ese Li	1986	6.3	7.3	8.0	12
45 Ese Li	1987	7.0	7.6	8.3	14
45 Ese Li	1988	6.5	8.0	10.5	19
45 Ese Li	1989	5.5	7.3	7.8	17
45 Ese Li	1990	7.3	8.8	9.7	15
45 Ese Li	1991	7.5	8.8	9.8	16
45 Ese Li	1992	7.3	8.9	9.8	15
45 Ese Li	1993	7.3	9.0	9.8	15
45 Ese Li	1994	7.0	7.9	8.8	18
45 Ese Li	1995	7.3	8.6	10.0	15
49 Green's	1983	6.1	7.2	9.0	5
49 Green's	1984	5.3	6.5	7.6	15
49 Green's	1985	6.3	7.4	8.5	15
49 Green's	1986	5.5	6.7	8.0	14
49 Green's	1987	6.2	7.4	8.3	14
49 Green's	1988	6.0	7.4	8.5	15
49 Green's	1989	6.0	7.7	10.0	17
49 Green's	1990	5.0	7.3	8.8	17
49 Green's	1991	5.0	6.9	8.5	19
49 Green's	1992	5.5	7.5	9.0	19
49 Green's	1993	7.0	8.2	9.3	18
49 Green's	1994	6.3	7.1	7.8	19
49 Green's	1995	6.0	7.4	8.6	18
61 West Pt	1983	7.8	8.9	9.6	9
61 West Pt	1984	7.5	8.4	9.7	13
61 West Pt	1985	7.6	9.6	10.9	13
61 West Pt	1986	6.6	7.7	8.6	12
61 West Pt	1987	7.7	8.3	9.4	11
61 West Pt	1988	7.9	8.8	9.6	15
61 West Pt	1989	7.3	8.6	10.5	15
61 West Pt	1990	7.8	8.8	9.3	12
61 West Pt	1991	7.5	9.2	10.5	18
61 West Pt	1992	6.6	9.2	10.0	19
61 West Pt	1993	9.3	10.1	11.5	13
61 West Pt	1994	7.6	8.7	9.9	17
61 West Pt	1995	6.5	8.7	10.4	14

Site	Year	Minimum Secchi Disk Transparenc (meters)	Average Secchi Disk Transparenc (meters)	Maximum Secchi Disk Transparenc (meters)	Sample Size
64 Jon Ldg	1984	7.6	8.7	9.4	12
64 Jon Ldg	1985	8.4	9.5	11.0	13
64 Jon Ldg	1986	6.1	7.8	9.1	12
64 Jon Ldg	1987	7.4	8.2	8.9	13
64 Jon Ldg	1988	7.5	8.6	9.6	15
64 Jon Ldg	1989	7.3	8.9	10.3	16
64 Jon Ldg	1990	8.3	9.2	10.5	12
64 Jon Ldg	1991	8.3	9.5	10.8	18
64 Jon Ldg	1992	6.5	9.5	10.7	19
64 Jon Ldg	1993	9.5	10.1	11.6	13
64 Jon Ldg	1994	7.6	8.8	10.0	18
64 Jon Ldg	1995	7.0	8.7	10.7	14

Historical Chlorophyll a Data (1984-1995)
[Lay Monitor Data]

Site	Year	Minimum Chlorophyll a Concentration (ppb)	Average Chlorophyll a Concentration (ppb)	Maximum Chlorophyll a Concentration (ppb)	Sample Size
45 Ese Li	1984	0.8	1.3	2.4	5
45 Ese Li	1985	0.4	1.1	3.6	7
45 Ese Li	1986	1.1	1.6	2.6	6
45 Ese Li	1987	0.5	1.0	1.4	7
45 Ese Li	1988	1.1	1.8	2.6	9
45 Ese Li	1989	0.9	1.3	2.2	9
45 Ese Li	1990	1.0	1.5	2.6	9
45 Ese Li	1991	1.2	1.6	2.1	9
45 Ese Li	1992	1.2	1.6	2.6	8
45 Ese Li	1993	1.1	1.4	1.8	8
45 Ese Li	1994	0.9	2.0	3.1	10
45 Ese Li	1995	0.9	1.5	2.1	8
49 Green's	1984	0.6	0.9	1.2	6
49 Green's	1985	0.6	0.9	1.6	7
49 Green's	1986	0.9	1.6	2.3	6
49 Green's	1987	1.2	1.8	2.7	7
49 Green's	1988	0.2	1.3	2.8	7
49 Green's	1989	0.8	1.3	1.9	8
49 Green's	1990	0.5	1.6	4.3	8
49 Green's	1991	1.1	1.8	2.8	9
49 Green's	1992	1.3	1.9	2.9	10
49 Green's	1993	1.2	1.9	4.8	9
49 Green's	1994	1.6	2.5	4.4	9
49 Green's	1995	0.9	1.7	3.9	9
61 West Pt	1984	0.4	0.6	0.8	4
61 West Pt	1985	0.6	0.9	1.1	5
61 West Pt	1986	0.8	1.1	1.5	6
61 West Pt	1987	0.6	1.0	1.4	6
61 West Pt	1988	0.9	1.6	3.1	8
61 West Pt	1989	0.7	1.4	2.0	9
61 West Pt	1990	1.0	1.8	3.1	8
61 West Pt	1991	1.1	1.8	3.7	11
61 West Pt	1992	0.9	1.6	2.4	10
61 West Pt	1993	0.9	1.2	1.7	7
61 West Pt	1994	0.8	1.6	2.4	10
61 West Pt	1995	0.8	1.2	2.4	8
64 Jon Ldg	1984	0.5	0.8	1.4	5
64 Jon Ldg	1985	0.4	0.8	1.1	7
64 Jon Ldg	1986	0.8	1.3	1.8	6
64 Jon Ldg	1987	1.0	1.3	1.7	6

Site	Year	Minimum Chlorophyll *a* Concentration (ppb)	Average Chlorophyll *a* Concentration (ppb)	Maximum Chlorophyll *a* Concentration (ppb)	Sample Size
64 Jon Ldg	1989	0.6	1.5	4.3	9
64 Jon Ldg	1990	1.0	1.9	3.5	8
64 Jon Ldg	1991	1.3	1.7	2.5	10
64 Jon Ldg	1992	0.9	1.8	2.9	11
64 Jon Ldg	1993	0.9	1.2	1.9	7
64 Jon Ldg	1994	1.0	1.8	2.7	10
64 Jon Ldg	1995	0.8	1.4	1.9	8

FBG Water Quality Data (July 25, 1995)

Site	Depth (m)	Chl a (ppb)	Diss. Color (ptu)	pH	CO_2 (ppm) pt.	Alkg end pt. (mg/l)	Alkp end pt. (mg/l)	SPCD (uS)	Total Phos. (ppb)
45 Ese Li	0-6.0	1.1	6.9	----	----	-----	-----	----	5.1
45 Ese Li	7.5	----	----	----	----	4.6	5.2	----	5.1
49 Green's	0-6.0	0.9	5.2	----	----	4.5	5.1	----	5.8
49 Green's	0.5	0.7	5.2	7.1	1.2	4.6	5.2	60.6	----
49 Green's	8.0	2.1	6.9	7.0	1.3	4.5	5.1	62.3	6.6
49 Green's	10.0	----	----	6.9	2.9	4.4	4.9	60.6	7.4
64 Jon Ldg	0-7.5	1.1	4.3	----	----	4.6	5.0	----	4.6
64 Jon Ldg	0.5	0.9	5.2	----	2.9	4.5	4.9	61.0	----
64 Jon Ldg	3.0	----	----	7.2	3.9	----	----	61.2	----
64 Jon Ldg	8.5	1.6	4.3	7.2	----	4.4	4.7	61.3	5.1
64 Jon Ldg	10.0	----	----	----	2.2	----	----	----	7.9

Site	Secchi Disk Transparency (meters)
45 Ese Li	Bottom (8.5 meters)
49 Green's	10.0 meters
64 Jon Ldg	10.8 meters

Site	Depth (m)	Temperature (°C)	Diss. Oxygen ppm)
45 Ese Li	0.10	25.1	7.9
45 Ese Li	0.50	25.0	7.8
45 Ese Li	1.00	24.8	7.8
45 Ese Li	1.50	24.6	7.8
45 Ese Li	2.00	24.5	7.8
45 Ese Li	2.50	24.4	7.6
45 Ese Li	3.00	24.3	7.8
45 Ese Li	3.50	24.1	7.7
45 Ese Li	4.00	24.0	7.9
45 Ese Li	4.50	23.6	8.0
45 Ese Li	5.00	23.4	8.0
45 Ese Li	5.50	23.3	7.9
45 Ese Li	6.00	22.9	8.1
45 Ese Li	6.50	21.9	8.3
45 Ese Li	7.00	19.7	9.1
45 Ese Li	7.50	17.0	9.9
45 Ese Li	8.00	16.0	9.9
49 Green's	0.10	24.8	7.9
49 Green's	0.50	24.7	7.7
49 Green's	1.00	24.3	7.8
49 Green's	1.50	24.2	7.8
49 Green's	2.00	24.1	7.8

Site	Depth (m)	Temperature (°C)	Diss. Oxygen ppm)
49 Green's	2.50	24.0	7.8
49 Green's	3.00	23.9	7.9
49 Green's	3.50	23.8	7.9
49 Green's	4.00	23.6	7.9
49 Green's	4.50	23.5	7.9
49 Green's	5.00	23.4	8.0
49 Green's	5.50	23.2	7.9
49 Green's	6.00	22.9	8.0
49 Green's	6.50	21.2	8.6
49 Green's	7.00	20.0	9.0
49 Green's	7.50	17.7	9.6
49 Green's	8.00	15.2	10.1
49 Green's	8.50	13.7	10.6
49 Green's	9.00	13.1	10.7
49 Green's	9.50	12.4	10.6
49 Green's	10.00	11.9	10.4
49 Green's	10.50	11.0	9.9
49 Green's	11.00	10.6	9.5
64 Jon Ldg	0.10	24.1	8.0
64 Jon Ldg	0.50	24.1	8.0
64 Jon Ldg	1.00	24.1	8.0
64 Jon Ldg	1.50	23.8	7.9
64 Jon Ldg	2.00	23.7	8.0
64 Jon Ldg	2.50	23.7	8.0
64 Jon Ldg	3.00	23.7	8.1
64 Jon Ldg	3.50	23.6	8.2
64 Jon Ldg	4.00	23.6	8.2
64 Jon Ldg	4.50	23.6	8.2
64 Jon Ldg	5.00	23.6	8.0
64 Jon Ldg	5.50	23.3	8.2
64 Jon Ldg	6.00	23.2	8.2
64 Jon Ldg	6.50	23.2	8.1
64 Jon Ldg	7.00	23.1	8.2
64 Jon Ldg	7.50	23.0	8.1
64 Jon Ldg	8.00	22.5	8.3
64 Jon Ldg	8.50	21.7	8.4
64 Jon Ldg	9.00	18.8	9.2
64 Jon Ldg	9.50	16.4	10.0
64 Jon Ldg	10.00	15.1	10.1
64 Jon Ldg	10.50	12.9	10.6

Long Island - Site 45 Ese Li
July 25, 1995

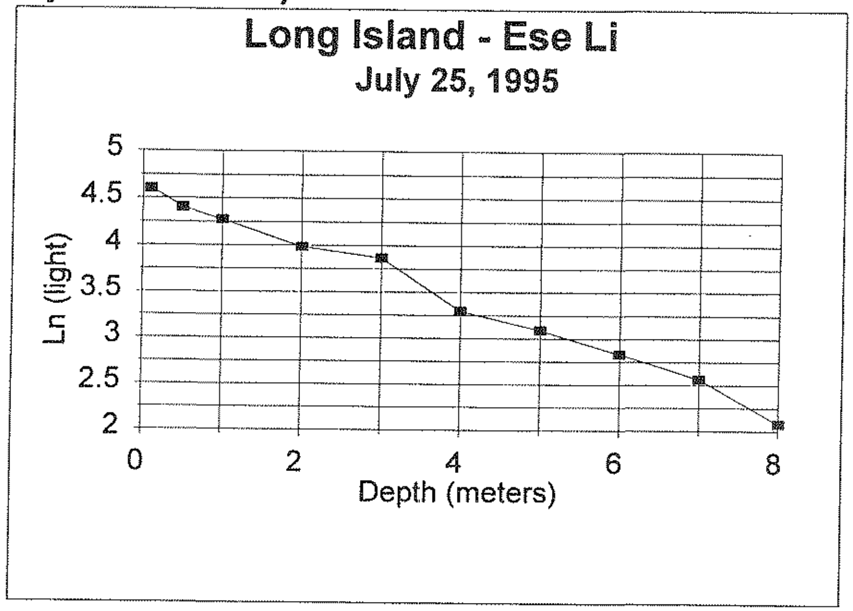
Light Data (presented as % light penetration)

Site	Depth (m)	Relative li	Ln(light)
45 Ese Li	0.10	100.00	4.61
45 Ese Li	0.50	82.00	4.41
45 Ese Li	1.00	72.00	4.28
45 Ese Li	2.00	54.00	3.99
45 Ese Li	3.00	48.00	3.87
45 Ese Li	4.00	27.00	3.30
45 Ese Li	5.00	22.00	3.09
45 Ese Li	6.00	17.00	2.83
45 Ese Li	7.00	13.00	2.56
45 Ese Li	8.00	8.00	2.08

Depth: Surface to 8 meters

Regression Output:

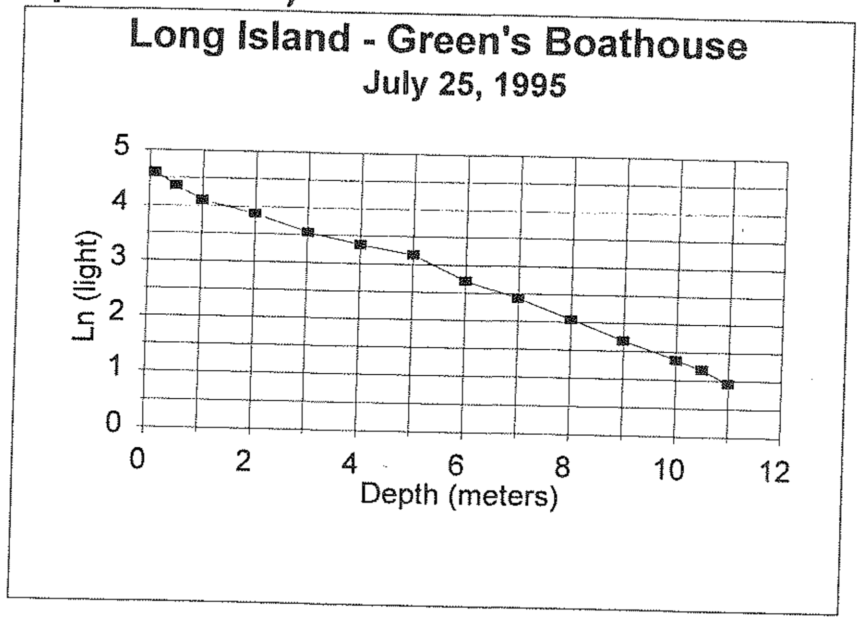
Constant		4.61
Std Err of Y Est		0.09
R Squared		0.99
No. of Observations		10.00
Degrees of Freedom		8.00
X Coefficient(s)	**-0.30 Slope**	
Std Err of Coef.	0.01	



Long Island - Site 49 Green's Boathous July 25, 1995

Light Data (presented as % light penetration)

Site	Depth (m)	Relative li	Ln(light)
49 Gr Bth	0.10	100.00	4.61
49 Gr Bth	0.50	78.30	4.36
49 Gr Bth	1.00	60.90	4.11
49 Gr Bth	2.00	47.80	3.87
49 Gr Bth	3.00	34.80	3.55
49 Gr Bth	4.00	28.30	3.34
49 Gr Bth	5.00	23.90	3.17
49 Gr Bth	6.00	15.20	2.72
49 Gr Bth	7.00	11.30	2.42
49 Gr Bth	8.00	7.80	2.05
49 Gr Bth	9.00	5.40	1.69
49 Gr Bth	10.00	3.90	1.36
49 Gr Bth	10.50	3.30	1.19
49 Gr Bth	11.00	2.60	0.96



Depth: Surface to 11 meters

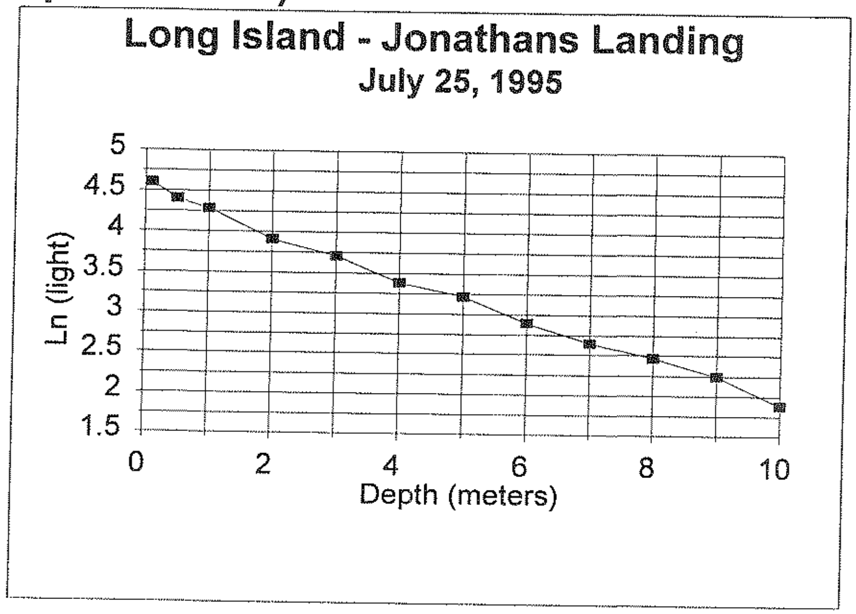
Regression Output:

Constant		4.57
Std Err of Y Est		0.09
R Squared		0.99
No. of Observations		14.00
Degrees of Freedom		12.00
X Coefficient(s)	**-0.32 Slope**	
Std Err of Coef.	0.01	

Long Island - Site 64 Johnathans Landi
July 25, 1995

Light Data (presented as % light penetration)

Site	Depth (m)	Relative li	Ln(light)
64 Jon Ld	0.10	100.00	4.61
64 Jon Ld	0.50	81.80	4.40
64 Jon Ld	1.00	72.70	4.29
64 Jon Ld	2.00	50.00	3.91
64 Jon Ld	3.00	40.90	3.71
64 Jon Ld	4.00	29.50	3.38
64 Jon Ld	5.00	25.00	3.22
64 Jon Ld	6.00	18.20	2.90
64 Jon Ld	7.00	14.10	2.65
64 Jon Ld	8.00	11.80	2.47
64 Jon Ld	9.00	9.50	2.25
64 Jon Ld	10.00	6.60	1.89



Depth: Surface to 10 meters

Regression Output:

Constant		4.52
Std Err of Y Est		0.07
R Squared		1.00
No. of Observations		12.00
Degrees of Freedom		10.00
X Coefficient(s)	**-0.26 Slope**	
Std Err of Coef.	0.01	

APPENDIX B

GLOSSARY OF LIMNOLOGICAL TERMS

Aerobe- Organisms requiring oxygen for life. All animals, most algae and some bacteria require oxygen for respiration.

Algae- See phytoplankton.

Alkalinity- Total concentration of bicarbonate and hydroxide ions (in most lakes).

Anaerobe- Organisms not requiring oxygen for life. Some algae and many bacteria are able to respire or ferment without using oxygen.

Anoxic- A system lacking oxygen, therefore incapable of supporting the most common kind of biological respiration, or of supporting oxygen-demanding chemical reactions. The deeper waters of a lake may become anoxic if there are many organisms depleting oxygen via respiration, and there is little or no replenishment of oxygen from photosynthesis or from the atmosphere.

Benthic- Referring to the bottom sediments.

Bacterioplankton- Bacteria adapted to the "open water" or "planktonic" zone of lakes, adapted for many specialized habitats and include groups that can use the sun's energy (phytoplankton), some that can use the energy locked in sulfur or iron, and others that gain energy by decomposing dead material.

Bicarbonate- The most important ion (chemical) involved in the buffering system of New Hampshire lakes.

Buffering- The capacity of lakewater to absorb acid with a minimal change in the pH. In New Hampshire the chemical responsible for buffering is the bicarbonate ion. (See pH.)

Chloride- One of the components of salts dissolved in lakewater. Generally the most abundant ion in New Hampshire lakewater, it may be used as an indicator of raw sewage or of road salt.

Chlorophyll a- The main green pigment in plants. The concentration of chlorophyll *a* in lakewater is often used as an indicator of algal abundance.

Circulation- The period during spring and fall when the combination of low water temperature and wind cause the water column to mix freely over its entire depth.

Density- The weight per volume of a substance. The more dense an object, the heavier it feels. Low-density liquids will float on higher-density liquids.

Dimictic- The thermal pattern of lakes where the lake circulates, or mixes, twice a year. Other patterns such as polymictic (many periods of circulation per year) are uncommon in New Hampshire. (See also meromictic and holomictic).

Dystrophy- The lake trophic state in which the lakewater is highly stained with humic acids (reddish brown or yellow stain) and has low productivity. Chlorophyll *a* concentration may be low or high.

Epilimnion- The uppermost layer of water during periods of thermal stratification. (See lake diagram).

Eutrophy- The lake trophic state in which algal production is high. Associated with eutrophy is low Secchi Disk depth, high chlorophyll *a*, and high total phosphorus. From an esthetic viewpoint these lakes are "bad" because water clarity is low, aquatic plants are often found in abundance, and cold-water fish such as trout and salmon are usually not present. A good aspect of eutrophic lakes is their high productivity in terms of warm-water fish such as bass, pickerel, and perch.

Free CO2- Carbon dioxide that is not combined chemically with lake water or any other substances. It is produced by respiration, and is used by plants and bacteria for photosynthesis.

Holomixis- The condition where the entire lake is free to circulate during periods of overturn. (See meromixis.)

Humic Acids- Dissolved organic compounds released from decomposition of plant leaves and stems. Humic acids are red, brown, or yellow in color and are present in nearly all lakes in New Hampshire. Humic acids are consumed only by fungi, and thus are relatively resistant to biological decomposition.

Hydrogen Ion- The "acid" ion, present in small amounts even in distilled water, but contributed to rain-water by atmospheric processes, to ground-water by soils, and to lakewater by biological organisms and sediments. The active component of "acid rain". See also "pH" the symbolic value inversely and exponentially related to the hydrogen ion.

Hypolimnion- The deepest layer of lakewater during periods of thermal stratification. (See lake diagram)

Lake- Any "inland" body of relatively "standing" water. Includes many synonyms such as ponds, tarns, loches, billabongs, bogs, marshes, etc.

Lake Morphology- The shape and size of a lake and its basin.

Littoral- The area of a lake shallow enough for submerged aquatic plants to grow.

Meromixis- The condition where the entire lake fails to circulate to its deepest points; caused by a high concentration of salt in the deeper waters, and by peculiar landscapes (small deep lakes surrounded by hills and/or forests. (Contrast holomixis.)

Mesotrophy- The lake trophic state intermediate between oligotrophy and eutrophy. Algal production is moderate, and chlorophyll *a*, Secchi Disk depth, and total phosphorus are also moderate. These lakes are esthetically "fair" but not as good as oligotrophic lakes.

Metalimnion- The "middle" layer of the lake during periods of summer thermal stratification. Usually defined as the region where the water temperature changes at least one degree per meter depth. Also called the thermocline.

Mixis- Periods of lakewater mixing or circulation.

Mixotrophy- The lake condition where the water is highly stained with humic acids, but algal production and chlorophyll *a* values are also high.

Oligotrophy- The lake trophic state where algal production is low, Secchi Disk depth is deep, and chlorophyll *a* and total phosphorus are low. Esthetically these lakes are the "best" because they are clear and have a minimum of algae and aquatic plants. Deep oligotrophic lakes can usually support cold-water fish such as lake trout and land-locked salmon.

Overturn- See circulation or mixis

pH- A measure of the hydrogen ion concentration of a liquid. For every decrease of 1 pH unit, the hydrogen ion concentration increases 10 times. Symbolically, the pH value is the "negative logarithm" of the hydrogen ion concentration. For example, a pH of 5 represents a hydrogen ion concentration of 10^{-5} molar. [Please thank the chemists for this lovely symbolism -- and ask them to explain it in lay terms!] In any event, the higher the pH value, the lower the hydrogen ion concentration. The range is 0 to 14, with 7 being neutral 1 denoting high acid condition and 14 denoting very basic condition.

Photosynthesis- The process by which plants convert the inorganic substances carbon dioxide and water into organic glucose (sugar) and oxygen using sunlight as the energy source. Glucose is an energy source for growth, reproduction, and maintenance of almost all life forms.

Phytoplankton- Microscopic algae which are suspended in the "open water" zone of lakes and ponds. A major source of food for zooplankton. Common examples include: diatoms, euglenoids, dinoflagellates, and many others. Usually included are the blue-green bacteria.

Parts per million- Also known as "ppm". This is a method of expressing the amount of one substance (solute) dissolved in another (solvent). For example, a solution with 10 ppm of oxygen has 10 pounds of oxygen for every 999,990 pounds (500 tons) of water. Domestic sewage usually contains from 2 to 10 ppm phosphorus.

Parts per billion-Also known as "ppb". This is only 1/1000 of ppm, therefore much less concentrated. As little as 1 ppb of phosphorus will sustain growth of algae. As little as 10 ppb phosphorus will cause algal blooms! Think of the ratio as 1 milligram (1/28000 of an ounce) of phosphorus in 25 barrels of water (55 gallon drums)! Or, 1 gallon of septic waste diluted into 10,000 gallons of lakewater. It adds up fast!

Plankton- Community of microorganisms that live suspended in the water column, not attached to the bottom sediments or aquatic plants. See also "bacterioplankton" (bacteria), "phytoplankton" (algae) and "zooplankton" (microcrustaceans and rotifers).

Saturated- When a solute (such as water) has dissolved all of a substance that it can. For example, if you add table salt to water, a point is reached where any additional salt fails to dissolve. The water is then said to be saturated with table salt. In lakewater, gaseous oxygen can dissolve, but eventually the water becomes saturated with oxygen if exposed sufficiently long to the atmosphere or another source of oxygen.

Specific Conductivity- A measure of the amount of salt present in lakewater. As the salt concentration increases, so does the specific conductivity (electrical conductivity).

Stratum- A layer or "blanket". Can be used to refer to one of the major layers of lakewater such as the epilimnion, or to any layers of organisms or chemicals that may be present in a lake.

Thermal Stratification- The process by which layers are built up in the lake due to heating by the sun and partial mixing by wind.

Thermocline- Region of temperature change. (See metalimnion.)

Total Phosphorus- A measure of the concentration of phosphorus in lakewater. Includes both free forms (dissolved), and chemically combined form (as in living tissue, or in dead but suspended organisms).

Trophic Status- A classification system placing lakes into similar groups according to their amount of algal production. (See Oligotrophy, Mesotrophy, Eutrophy, Mixotrophy, and Dystrophy for definitions of the major categories)

Z- A symbol used by limnologists as an abbreviation for depth.

Zooplankton- Microscopic animals in the planktonic community. Some are called "water fleas", but most are known by their scientific names. Scientific names include: *Daphnia*, *Cyclops*, *Bosmina*, and *Kellicottia*.